
# INSTRUMENTMAN 3 & 2

## NAVY TRAINING COURSES

NAVPERS 10193-A

# INSTRUMENTMAN
# 3 & 2

PREPARED BY

**BUREAU OF NAVAL PERSONNEL**



**NAVY TRAINING COURSES**

**NAVPERS 10193-A**

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1951

First edition 1949

Reprinted 1951

Reprinted with changes 1961

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price $1.25

# PREFACE

This book has been written for the purpose of helping enlisted men to secure promotions to the ratings of Instrumentman 3 and Instrumentman 2. It is one of the series of NAVY TRAINING COURSES designed to give men of the Navy the background information necessary to secure advancement in rating.

Qualifications for the rates of Instrumentman 3 and Instrumentman 2 are listed in an appendix at the back of the book. This training course contains information on all the technical qualifications for both rates. Because examinations for promotions are based exclusively on these examinations, it is suggested that men refer to them frequently for guidance.

This course covers watch and clock repairing, office machine repairing, and the maintenance and adjustment of Navy gages. Beginning with a brief review of the history of clock and watch development, it gives you helpful information on the making of watch parts, the watch casualty analysis, the cleaning and oiling of watches and clocks, and the theory of operation of these timepieces. The course continues with an explanation of typewriter repairing, and then describes the procedures for repairing pressure and vacuum gages, tank level indicators, and other commonly used gages. It concludes with a chapter on the repair of the mechanical parts of electrical meters.

As one of the NAVY TRAINING COURSES, this book was prepared by the Naval Reserve Training Publications Center of the Bureau of Naval Personnel in cooperation with naval establishments and personnel especially cognizant of the duties of Navy Instrumentmen.

## CREDITS

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## STUDY GUIDE

The following table indicates which chapters of this manual apply to your rating. To use the table, follow these rules:

1. Select the column which applies to your rating. If you are in the regular Navy, you will use the column headed IM. If you are a member of the Naval Reserve, you will use the column headed by your particular emergency rating — IMW, IMO, or IMI.

2. Observe which chapters have been marked in your rating column with the number of the rate to which you are seeking advancement.

3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. In order to gain a well-rounded view of the duties of the general service, it is recommended that you read the other chapters of this manual even though they do not pertain directly to your rating.

4. For example: if you are a member of the Naval Reserve studying for advancement in rating to Instrumentman (Instrumentman Repairman) 2d class, you will select the column headed IMI. Following this column down, you will observe that you must study chapters 1, 8, 13, 14, 15, and 16.

| *CHAPTER* | *IM* | *IMW* | *IMO* | *IMI* |
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## REFERENCE READING

1. *Use of Tools* NavPers 10623.
2. *Basic Machines*, NavPers 10624.
3. *Use of Blueprints*, NavPers 10621.
4. *Mathematics*, NavPers 10069 and NavPers 10070.
5. *Electricity*, NavPers 10622–A.
6. *General Training Course for Petty Officers*, NavPers 10602A.
7. *Bureau of Ships Manual*, chapter 87, Mechanical and Measuring Instruments.
8. *Bureau of Ships Manual*, Chapter 69, Electrical Measuring and Test Instruments.

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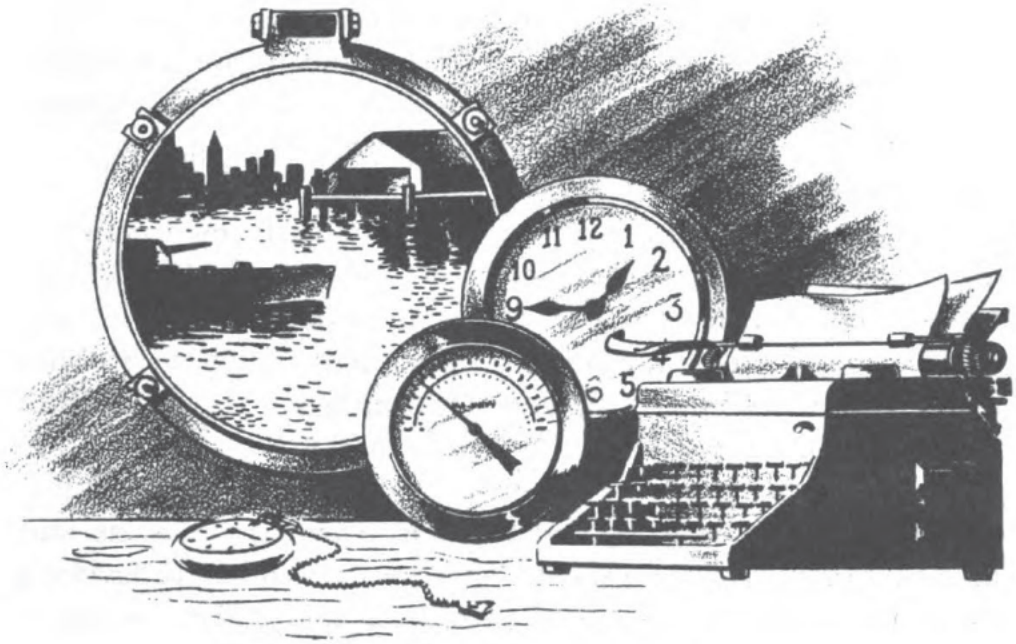


## CHAPTER 1

# AFLOAT AND ASHORE

A big battlewagon leaves port at 0600 tomorrow. The word has been passed, the lighting off schedule and the watch list have been typed and posted. At 0200 the steaming watch is called; the senior man checks the temperature, pressure, and tank gages in the fireroom. Hundreds of other jobs are being completed all over the ship. At 0500 the main engines are jacked over by steam, and all hands stand by at their stations ready to get the big ship moving. At 0600, when the first underway bell sounds, the ship begins to vibrate gently. She slowly starts to move, then glides majestically out to sea, *exactly on schedule* — a living symbol of your Navy's military strength and dependability. And, although not aboard, the Instrumentman has once more proved his worth.

The Instrumentman. Who is the Instrumentman? What does he do? Where does he work? Why is his work important?

The answers to these questions may influence your whole Navy career. So center your attention here for a few minutes. Try to visualize the Instrumentman and his duties as they are

described for you below. If you have mechanical ability, if you like to use tools to make and fix things, and if you are willing to work and study so as to improve your skill and your knowledge of the equipment on which you work — then you have the basic qualifications you need to strike for this rating.

First, in case you don't already know it, Instrumentman is a new rating. It was authorized on 10 February 1947. Briefly stated, the Instrumentman's job is to install, test, calibrate, overhaul, and repair mechanical instruments, such as watches and clocks, office machines, gages, and meters. He also repairs the mechanical parts of electrical measuring instruments. This covers most of the Navy's small precision mechanical instruments. As you can readily see, learning to repair and maintain this kind of equipment is well worth while. It develops manual skill and the technical knowledge that will make you a valuable man to the Navy — the kind of man the Navy wants — and it earns you the respect and confidence of your shipmates.

You just saw how Navy ships operate on schedule, largely because of the clocks and watches, office machines, and gages which they carry. In the same way, typewritten orders and mimeograph bulletins expedite much of the Navy's clerical work. In time of battle, commands are given, guns are fired on split-second timing, and all fleet movements are controlled with the help of instruments. Yes, the Instrumentman who keeps this vital equipment operating efficiently 24 hours a day is an important man in the modern Navy.

## PURPOSE OF THIS COURSE

The purpose of this course is to give an understanding of the principles and operation of the Navy's precision instruments on which the Instrumentman works. It provides a foundation for the advancement in rating from Instrument 3 and 2, and will also assist the striker seeking his rating as IM 3. It assumes a knowledge of the information contained in these two basic Navy courses:

1. *Bluejackets' Manual.*
2. *General Training Course for Petty Officers,* NavPers 10602A.

Ask your educational or divisional officer for these two

manuals. And then absorb their contents just as fast as you can. You'll need all of the information contained in these two books before you can assume the responsibilities of a Petty Officer.

Not only must you acquire familiarity with a PC's duties, but you should also have certain knowledge basic to the IM rating. For this you will find the following *Navy Training Courses* very helpful:

1. *Mathematics*, NavPers 10669, and 10070.
2. *Use of Blueprints*, NavPers 10621.
3. *Use of Tools*, NavPers 10623.
4. *Basic Machines*, NavPers 10625.

This course alone cannot make you a good Instrumentman, for that involves learning practical factors as well as studying. Cultivate physical as well as mental skills. Manual dexterity (ability to do good work with your hands) is important in this rating.

## STUDYING THIS COURSE

In studying this course, start by first noting the chapter heading and looking through the entire chapter to get a general idea of the material presented there. Then go back and note the major headings in the chapter, trying to fix them in your mind by subjects. After you have discovered the general purpose of the chapter, go back to its beginning and read through each paragraph, slowly and understandingly, *staying with it* until you are sure that you have learned all the *key points* that it contains. Don't pass over a single sentence until you know what it means. Take all the time you need for your study — there is no reason to rush through it.

After completing a chapter, take the QUIZ and try to answer all the questions listed for that chapter.

That is the way to study *anything* if you really want to learn it. If you didn't learn to study in school, you can start learning now. Try it tonight. It's a sure-fire method that has brought results for others, and it will bring results for you. Remember — study slowly, fix *every point* in your mind as you go, then check yourself by answering the QUIZ questions.

## WHAT'S IN THIS COURSE

Chapters 2 through 7 of this manual cover the subject of *Watch and Clock Repair* as it is done in the Navy. The theory and the principles of operation of these instruments are given, along with the procedures commonly used for repairing and adjusting them. All the fundamentals of the subject are covered. Incidentally, this is the first time that all this information for the student watch repairman has been presented anywhere under one cover. From these chapters, you can learn all of the theory on this subject that you will need to pass your IM 3 and 2 examinations.

The section on *office machine repair*, chapters 8 through 12, contains the principles and basic procedures of typewriter and other office machine repair. It supplies all the information that you will need in order to disassemble, clean, reassemble, and adjust any of the standard Navy typewriters (Underwood, Remington, Royal, and L. C. Smith).

Chapters 13 through 16 cover the theory and the principles of operation of pressure, vacuum, and temperature gages, fluid meters, tank level indicators, and combustion control instruments. This section also describes the operating principles of electrical meters and the procedures for repairing their mechanical parts.

This manual also contains, as appendixes, a glossary of terms for each section. Whenever you come across a word which you do not understand, look it up in the appropriate glossary. You can quickly acquire a lot of information by making frequent use of these glossaries.

Instrument repair, especially clock and watch repair, requires study. Read other books on the subject whenever you can. A separate watch repair reading list is given in appendix II, to help you with your outside study of that subject.

After reading this, you may feel that the Instrumentman has a great deal to learn. You are right — he *does* have a lot to learn. The three fields in this rating call for considerable theoretical knowledge and will each require a great deal of practical work experience. However, you have to learn only

one subject at a time, and you will be given the opportunity, as your training progresses, to learn all three subjects. You'll probably become highly proficient in one of these fields — the one of your choice.

## WHAT THE INSTRUMENTMAN DOES

As stated above, the Instrumentman is a skilled Navy mechanic who installs, tests, calibrates, and repairs clocks and watches, office machines, and gages of various types. Through his skill, the efficiency and safety of Navy ships and offices everywhere are maintained continuously at a high level.

## TECHNICAL DUTIES

The duties of Instrumentman 3 consist, for the most part, of cleaning and adjusting these instruments, and making the simpler repairs. In this way, he comes to learn the fine points of this work — the things which require greater skill and wider experience.

The Instrumentman 2 has acquired a certain degree of skill and is allowed to handle the tougher repair jobs coming into the instrument shop. He uses all the special hand tools, and the common power-driven tools like the lathe and grinder. In addition, he analyzes troubles on the instruments and makes every needed type of repair and adjustment.

In each case, you will receive instructions from your supervisor. He is an expert who has probably spent many years of his life doing this kind of work. Listen to his suggestions, and try to carry them out to the letter. Perform all the practical tasks that he gives you to do. Don't be satisfied until you have completed each task in a good, workmanlike manner. Remember, to advance in rating you must be recommended to the divisional officer by your superior or by a leading Petty Officer.

In appendix III of this manual you will find the qualifications for Instrumentman ratings. You'll notice that IM 2 must know everything that IM 3 knows, and in addition must have more knowledge of, and skill in, instrument repair procedures. The course, in general, is designed for the striker and the Instrumentman 3 who wants to advance.

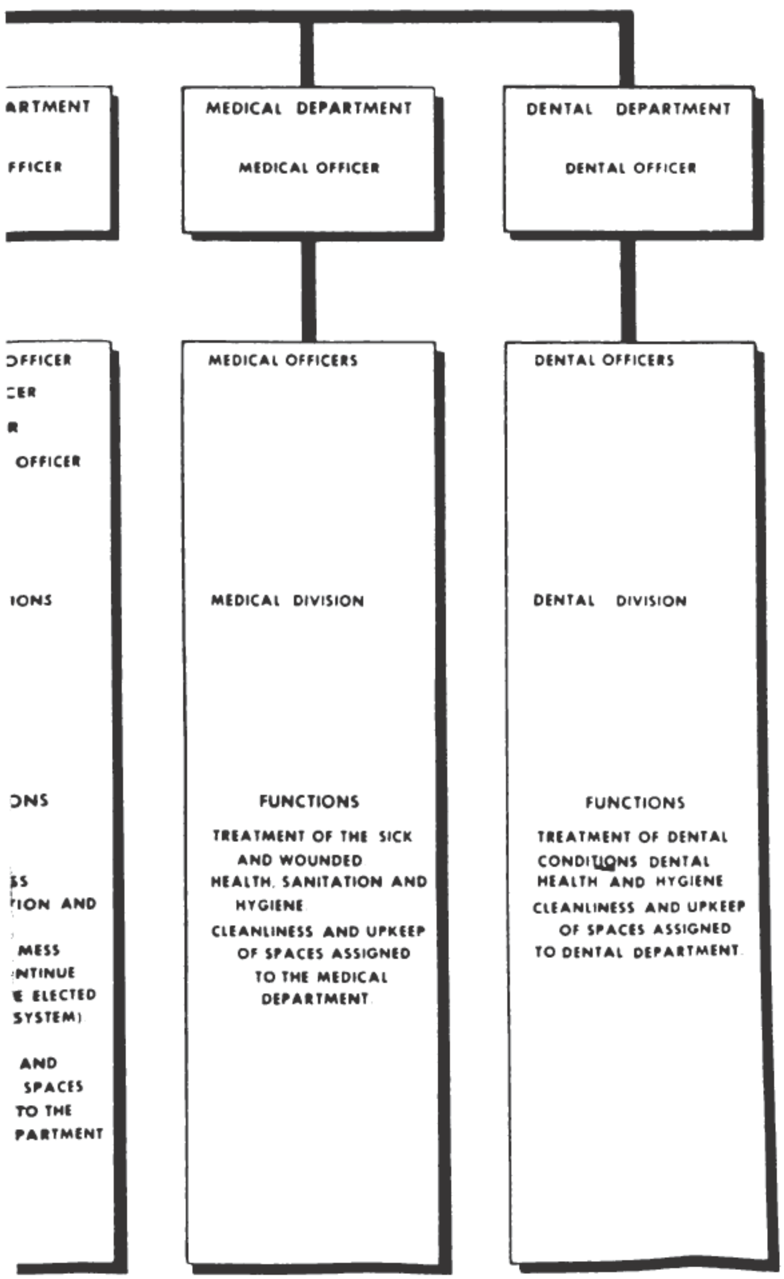
Instrumentmen may advance to Warrant Machinist (7442), (Instrument Technician), broadening their training and work experience to include the functions of optical instrument repair. Machinists (7442) are assigned for duty on repair ships, in overhaul shops aboard tenders and repair ships, and at shore repair activities.

## MILITARY DUTIES

As an Instrumentman, you'll also have some military duties. In fact, your military duties take precedence over your technical duties. You should become familiar with what is required of a Master at Arms, a Shore Patrolman, a Petty Officer with day duty so that when called upon, you can perform their duties along with the other PO's of your pay grade. (You will find all this information in the GENERAL TRAINING COURSE FOR PETTY OFFICERS).

The watch quarter and station bill, posted in conspicuou places about the ship, shows your assignment. Consult it often so that you will always know your military job on the ship.

Figure 1.—Instrumentman working on Navy repair ship.



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HEALTH, SANITATION AND HYGIENE.
CLEANLINESS AND UPKEEP OF SPACES ASSIGNED TO THE MEDICAL DEPARTMENT.
DENTAL OFFICERS
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## WHERE YOU WILL WORK

Since there are not enough Instrumentmen and repair equipment to provide a repair shop board each fighting ship, these ships usually go to a naval shipyard where the repair work is done. Ships far out at sea go to a repair ship or tender at some advanced base. In peace time, many of these repair ships are based at naval shipyards in the United States. As an Instrumentman, you will probably work on a repair ship; or you may be stationed in an instrument repair shop in one of the naval shipyards.

Later on, if you become proficient in your duties and make first or Chief, you may be selected to instruct in instrument repair at the U. S. Naval School, Instrumentman, Class A. This is a good billet, and you may draw the assignment after you have proved your ability.

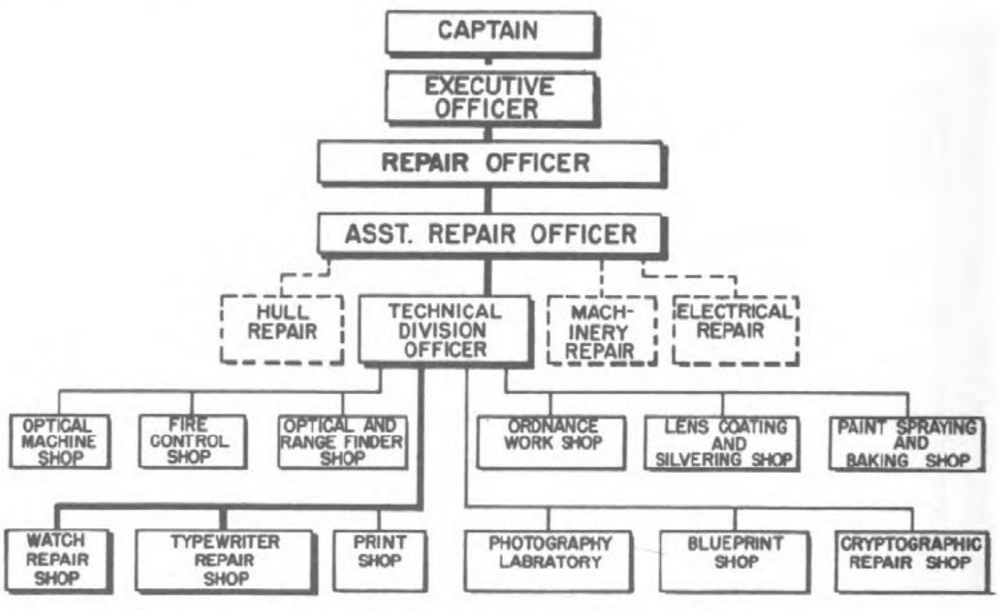


Figure 3. — Typical technical division on repair ship organization.

## ORGANIZATION

The Instrumentman progresses through the seaman group. On a repair ship or tender, he will be assigned to a division in the repair department. The different departments, their functions, and the chain of command are shown in figure 2.

The standard ship's organization is also shown in this chart.

Study it, and notice particularly how your repair department fits into this organization. A typical technical division organization on a repair ship is shown in figure 3. The gage shop on this ship is in the machine repair division.

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Now that you know who the Instrumentman is, let's take a closer look at the details of his job.

## QUIZ

1. What are the duties of the Instrumentman?
2. Where does the Instrumentman work?
3. In which department of a repair ship does the Instrumentman usually work?
4. Does the Instrumentman have any military duties?
5. Of what use is the PETTY OFFICER'S MANUAL to an Instrumentman?

# CHAPTER 2
# TIMEKEEPERS — OLD AND NEW

## EARLY TIMEKEEPERS

The first timekeeper was the sundial. No one knows just when primitive man first started to tell time by shadows from trees or rocks, but sundials were used in Babylonia before 2000 B. C. By the Middle Ages, elaborate and intricate sundials were built on monasteries and cathedrals, and in castle courtyards.

The clepsydra, or Greek water clock, was the second timekeeping device. In its simplest form, this was an earthen vessel with a small hole in the bottom. Filled with water, it always emptied itself in about the same length of time. This timekeeper was independent of the sun, and told time during the night hours. In dry countries sand was substituted for water, resulting in the sand glass. (See figure 4.) Later, mechanical models were developed which moved hands on dials, opened doors, and blew trumpets. Notched candles and graduated oil lamps came next. Although only rough timekeepers, they kept time satisfactorily and were used in monasteries and public buildings.

## MODERN MECHANICAL CLOCKS

By the eleventh century, clocks in the modern sense of the word had begun to develop. Some of these clocks had dials measuring 8 to 10 feet across. They had models which indicated moon-phases and movements of the heavenly bodies. Their roughly fashioned parts usually came from the blacksmith's shop; they ran 3 or 4 hours without attention and could strike

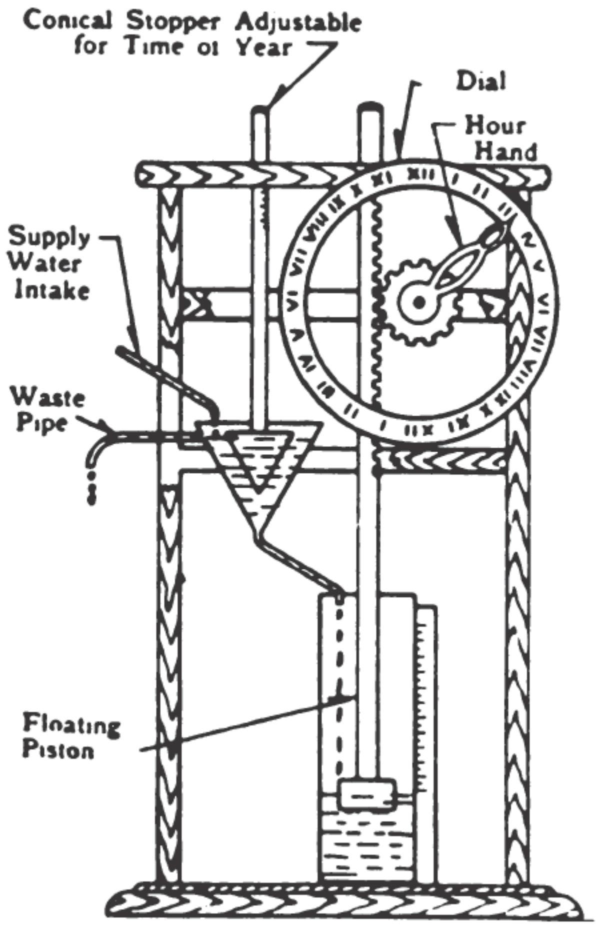



Figure 4.— An improved form of clepsydra in Greek and Roman times.

the hour. They were built on many of the famous cathedrals, town halls, and bridges of the time. Later, a crude arrangement for regulating their rate of running was invented and added to them, and these ponderous old timekeepers became the ancestors of our modern clocks. Yet in the fourteenth century, the best clocks could not keep time without gaining or losing as much as 2 hours a day.

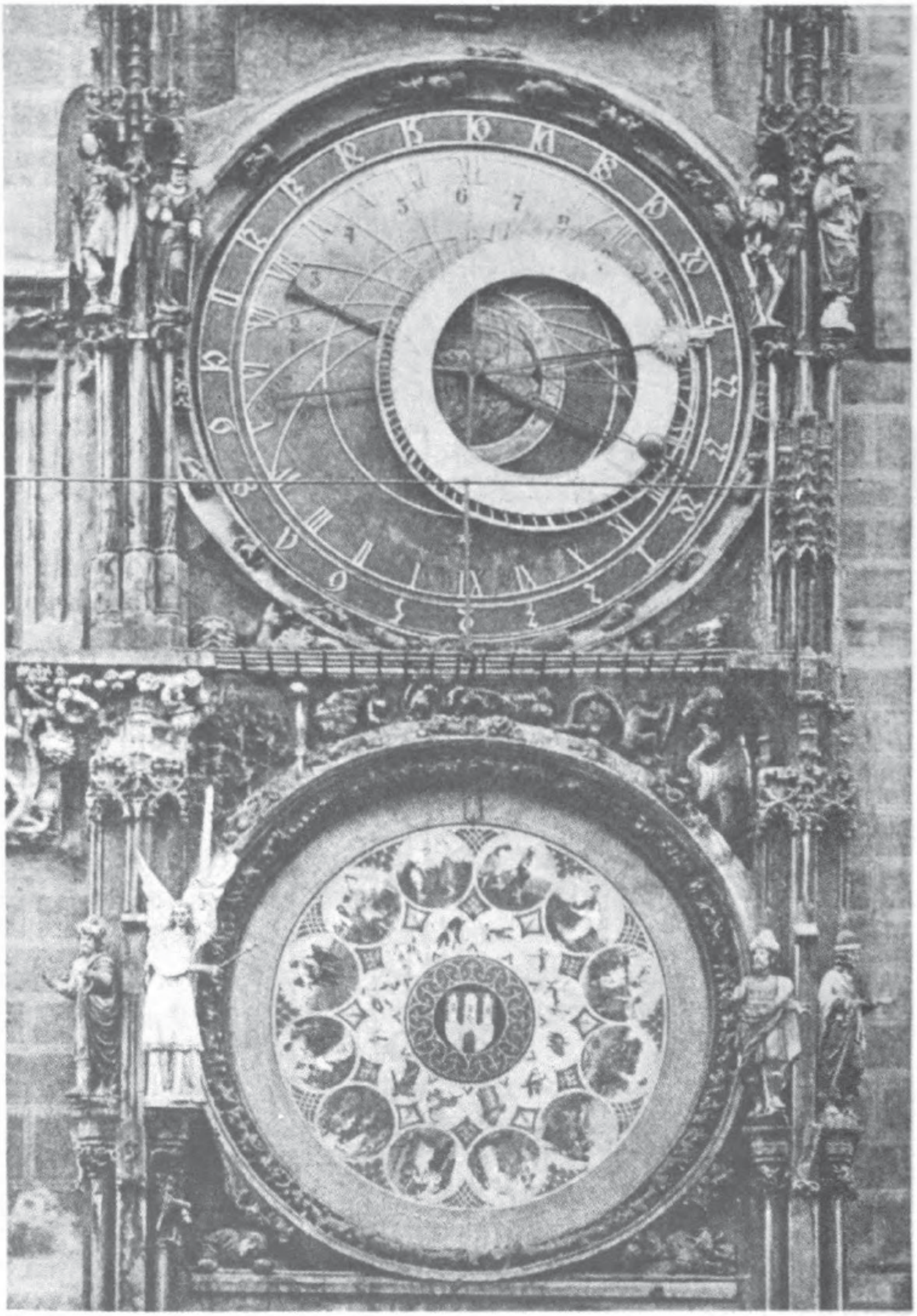


Figure 5.—A famous old clock at Prague, Czechoslovakia (about 1500). Upper dial is a perpetual calender. Lower dial shows motions of sun and moon.

Many weight-driven clocks of elaborate design were installed in the cathedrals and public buildings of Europe from 1500 to

1650. Some of those, besides striking the hours, showed the heavenly bodies and calendar changes. (See figure 5).

In the middle 1600's smaller domestic clocks were to be found almost everywhere, especially in England. They had only one hand — the hour hand. One truly beautiful type was the lantern clock, made of shining brass and operated by weights with long falls.

The invention of the pendulum in 1658 revolutionized the construction and accuracy of clocks. It was applied to all kinds of clocks at once. Other improvements followed. Clocks were fitted with minute hands and hour hands, and with temperature-controlled pendulums. Then, when someone enclosed the pendulum and weights in a large wooden case which would stand on the floor, the first grandfather clock was born.

Such stalwart American pioneer clockmakers as Eli Terry, Seth Thomas, and Chauncey Jerome made quality clocks of various types in New England from 1800 to 1850. These men invented many improvements and refinements. Some of their finest clocks, remodeled, are still in use today. Their wooden shelf clocks and bronze looking-glass clocks with painted scenes, carved pillars, and highly ornamental tops are good examples of their art.

Peter Henlein, of Nuremburg, by inventing the mainspring for clocks about 1500, became the father of the modern pocket watch. By 1600 a great variety of many-sided, oval, and circular-shaped pocket watches, in beautiful hand-chased or engraved cases, were in use all over Europe. (See figure 6.) Jewels in watches were introduced about 1700, greatly increasing their accuracy.

Watches were first made in America by colonial watchmakers from England and Holland. The first American watch factory, owned by Aaron L. Dennison and Edward Howard, was opened at Roxbury, Mass., around 1850 and was highly successful from the start. Using modern factory methods, automatic machinery, and precision-made interchangeable parts, American watch-makers since that time have consistently exercised great ingenuity and mechanical genius in making progressively better and more accurate watches. By so doing, they developed watch-

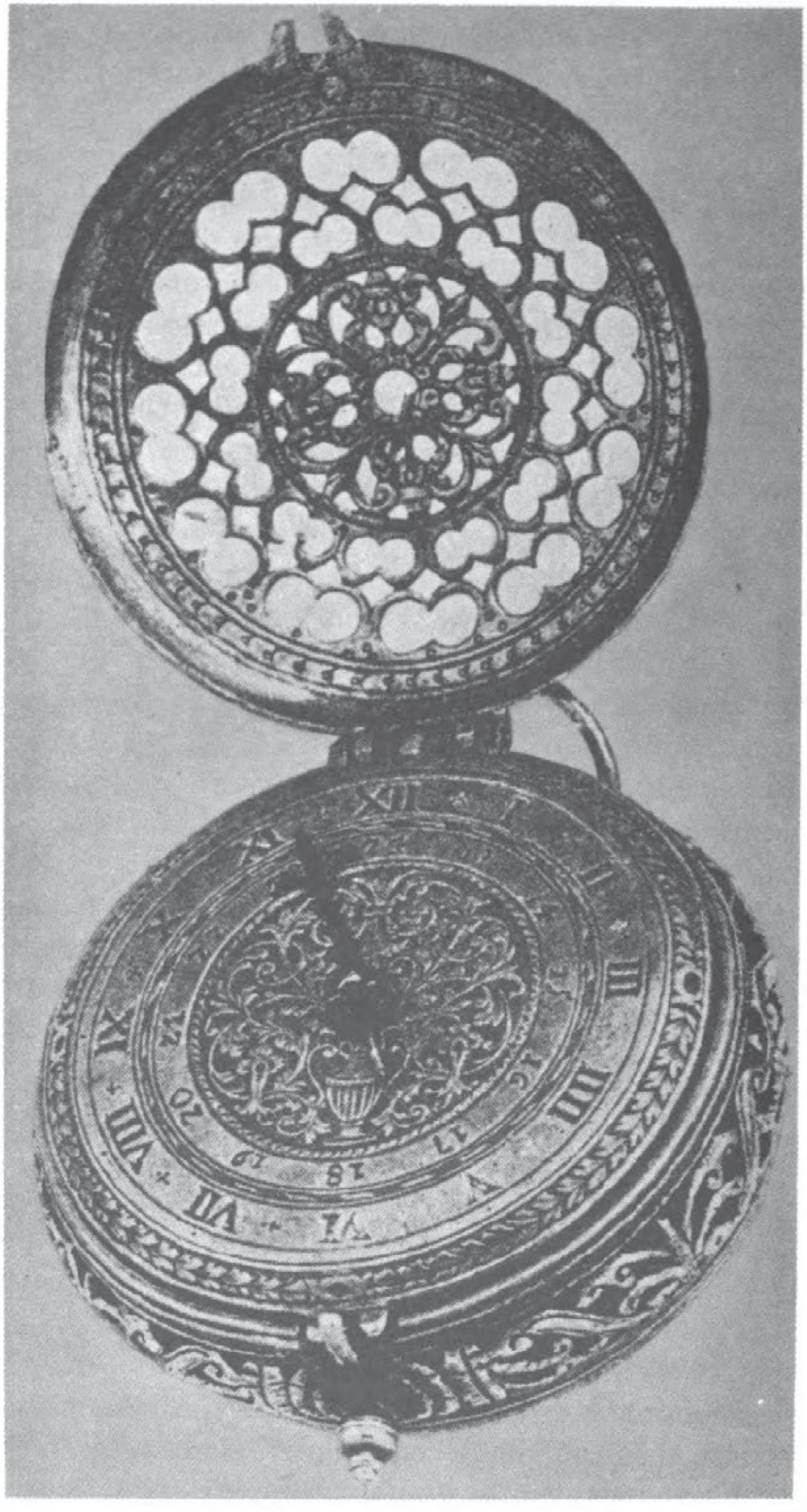


Figure 6. — A transitional sixteenth century watch (2½ inch diameter).

making in America to the position of world supremacy which it holds today.

## WHY SHIPS NEED TIMEKEEPERS

Early mariners had to chart their ship's course by estimating its direction, speed, and drift. Invention of the sextant in 1730 made possible the accurate determining of latitude, or north-south position. Finding the longitude was more difficult. Ships of that day often sailed directly to the desired latitude, and then, turning east or west, sailed till they reached their destination.

After 1730 the popular method of finding longitude called for an almanac, a sextant, and an accurate source of time. By means of the almanac and sextant the navigator could learn his local time at sea. But he did not know exactly by how much his local time differed from that at zero meridian, or Greenwich. If he had known the time difference, he could have figured his longitude from the relation: 24 hours equals 360 degrees. The sandglass used by ships in those days gave only approximate time readings. Obviously, an *accurate* timepiece was urgently needed. This challenge was met in 1761 by John Harrison, an Englishman, who created a timepiece which assured finding a ship's longitude to within half a degree. Navigation then became almost an exact science. Harrison's invention, later named a chronometer, has been improved since his time, but it still remains indispensable to navigation.

## MAJOR UNITS OF THE WATCH

Remember the first time you looked at the insides of a watch — all those tiny wheels, gears, and springs you saw, dancing back and forth before your eyes? Didn't it seem complicated?

Actually, the watch mechanism isn't nearly as complicated as it seems. By considering each unit separately and understanding its purpose as you go, you can easily learn the construction of a watch movement and the particular job of each of the parts.

The watch can be said to consist of four major units; the driving mechanism, the transmitting mechanism, the controlling

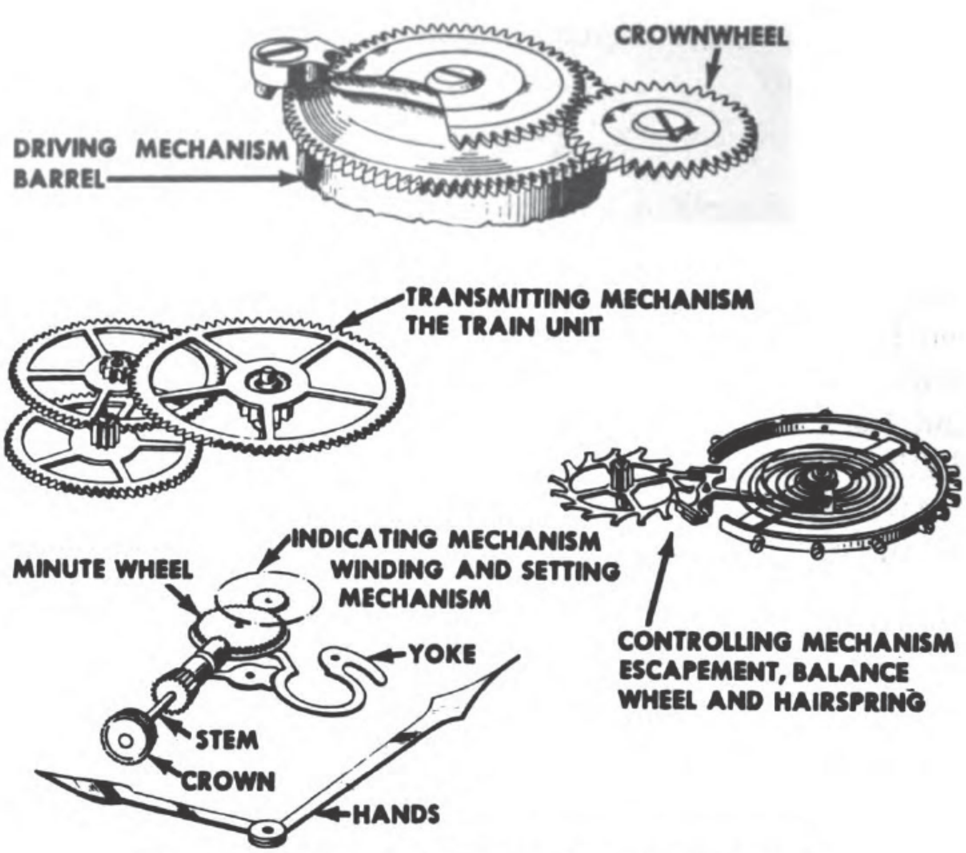



Figure 7.—Semiexploded view of the watch mechanism.

mechanism, and the indicating mechanism. These parts are illustrated in figure 7.

The driving mechanism contains the mainspring coiled in a barrel. The transmitting mechanism consists of three cogged wheels with pinions (small gears) mounted on their arbors, or shafts. The controlling mechanism is made up of balance wheel, balance spring, detached lever, and escape wheel. The indicating mechanism includes the hands and dial and the under-the-dial mechanism. Some of these terms will be new to you, but you'll soon learn to know them.

Now let's look at these units a little more closely. (Later chapters in this course will discuss each part in greater detail.)

## THE DRIVING MECHANISM

This unit consists of the mainspring coiled around an arbor within a barrel. Figure 8 shows the parts of a barrel and mainspring assembly. This is also called the power unit. The main-

spring is simply a coiled ribbon of steel, one end fastened to the inside of the barrel and the other to the arbor inside the barrel.

The edge of the rotating barrel, or a wheel attached to it, has teeth which mesh in the leaves of the pinion on the first arbor of the transmitting mechanism. This is the going barrel construction found in all American-made watches.

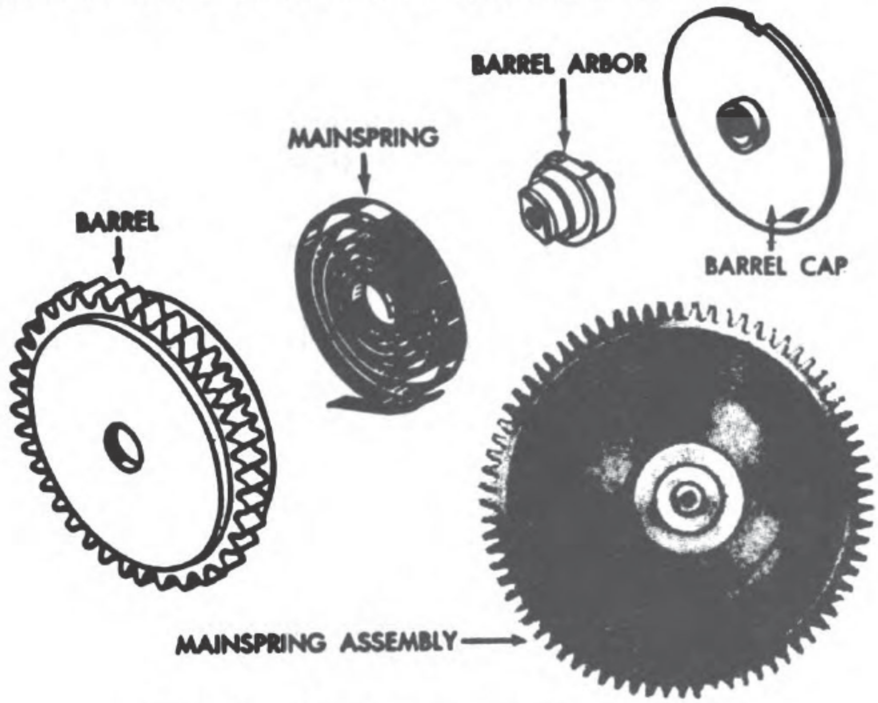



Figure 8.—Barrel and mainspring assembly parts.

A mainspring makes the barrel rotate once in eight hours, or three times in 24 hours. The barrel usually turns five times before the mainspring completely uncoils and the watch runs down. That means modern watches are made to run 40 hours. A ratchet and *click*, or pawl, must always be associated with a mainspring, so that it will not immediately uncoil as soon as it is wound up.

## THE TRANSMITTING MECHANISM

The transmitting mechanism is the train of wheels and pinions which transmits the power from the mainspring barrel to the pallet of the controlling mechanism. This train unit, as it is sometimes called, is shown in figure 9. It includes the center wheel and pinion, third wheel and pinion, fourth wheel and

pinion, and the escape wheel and pinion. It also supports the hands of the watch. The center wheel arbor turns once in an hour. The third wheel arbor turns 7½ times per hour, and the fourth wheel arbor turns 60 times per hour. The escape wheel in the controlling unit mechanism turns 10 times per minute, or 600 times an hour.

Since the escape wheel has 15 teeth, 15 x 600 (9,000), escape wheel teeth will pass a given point in an hour. Each escape wheel tooth delivers two impulses to the pallet, so in one hour the escape wheel teeth will deliver 9,000 x 2 (18,000) impulses to the balance wheel.

The arbors of a watch terminate in burnished pivots which run in jewel holes. Jeweled bearings add greatly to the watch's accuracy because they reduce friction. Most Navy comparing watches have 17 jewels. Navy stop watches have 7 and 15 jewels. You can see 7 jewels in figure 10. These jewels are

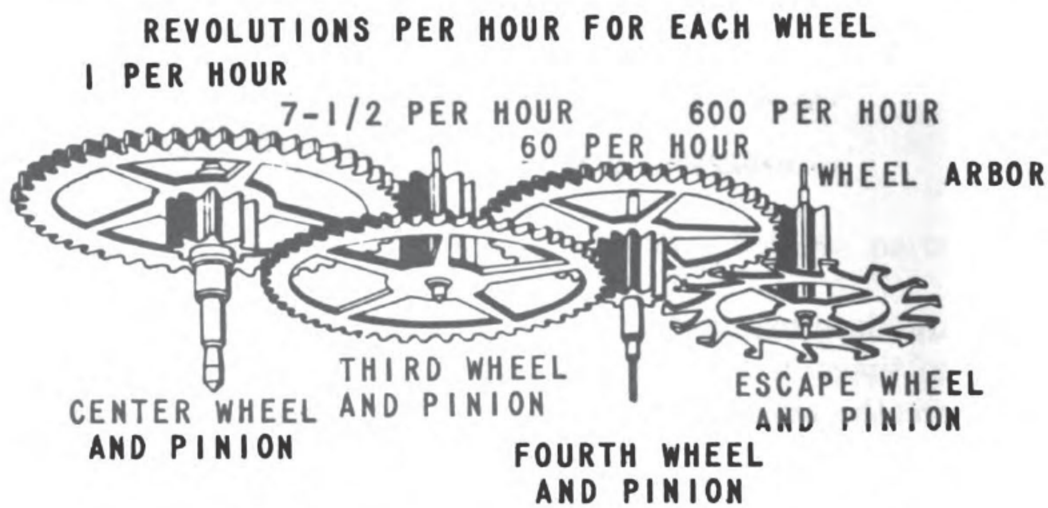



Figure 9.—The train unit, with wheel speeds (18,000 swings per hour).

shaped with an oil reservoir that holds an 8 to 18 months' supply of oil. This jewel design also prolongs the life of the watch. (See chapter 6 for a more detailed discussion of jeweling in watches.)

Now that you have learned about the driving and transmitting mechanism, and before you go on to the controlling and indicating mechanism, you might like to see an illustration of the basic parts of the watch in operating position (figure 11).

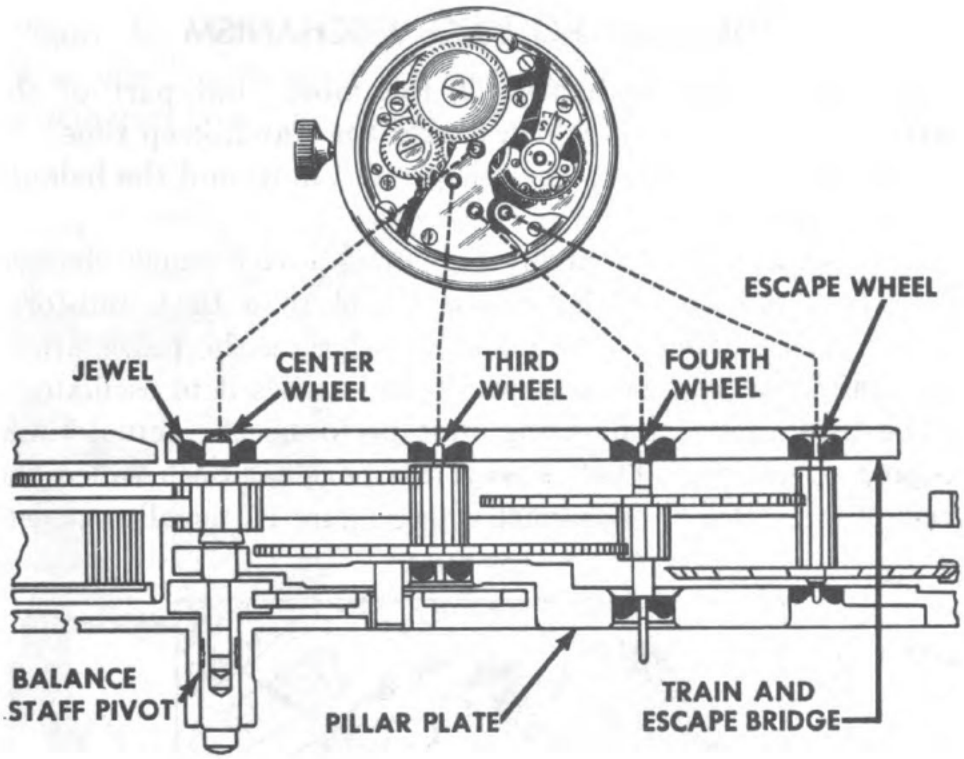



**Figure 10. — Side view of train, showing jewel positions.**

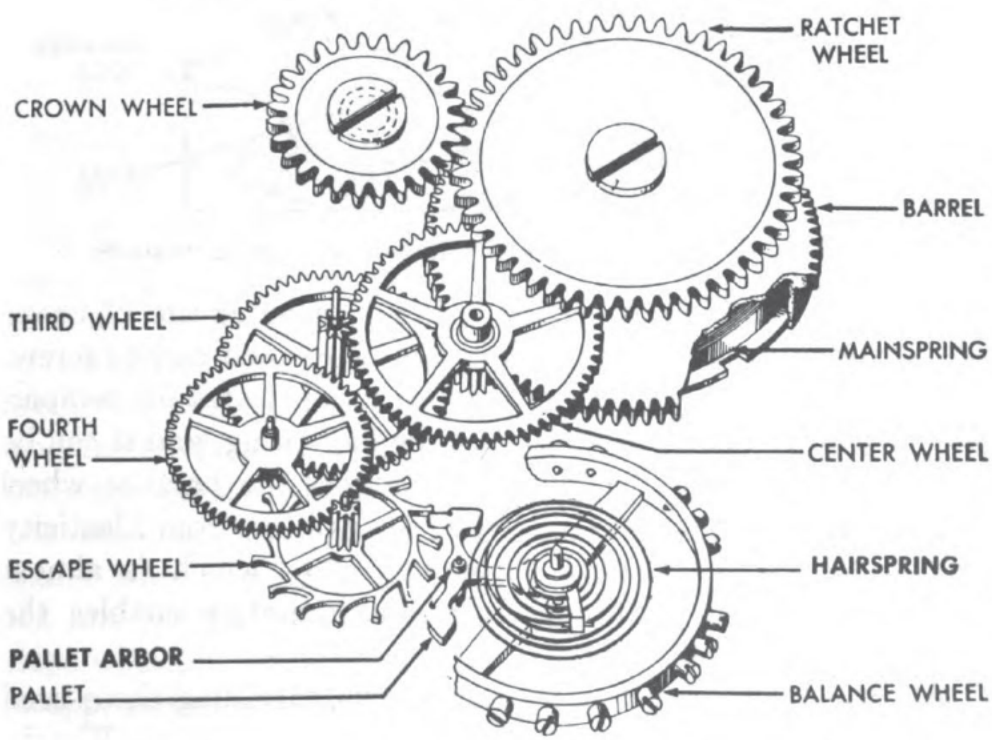



**Figure 11. — The basic parts of a watch in their operating position.**

## THE CONTROLLING MECHANISM

The controlling mechanism is the most vital part of the watch, for it is the part which makes the watch keep time. It is made up of two units; the escapement unit, and the balance and hairspring unit.

The escapement is a highly ingenious device which changes the rotary motion of the escape wheel to a back-and-forth motion of the pallet. The pallet, rocking on the pallet arbor, gives the balance wheel an impulse and causes it to oscillate.

The balance and hairspring unit performs the actual timekeeping operation. That is why this part has been called the brain of the watch. The balance wheel, figure 12, usually consists

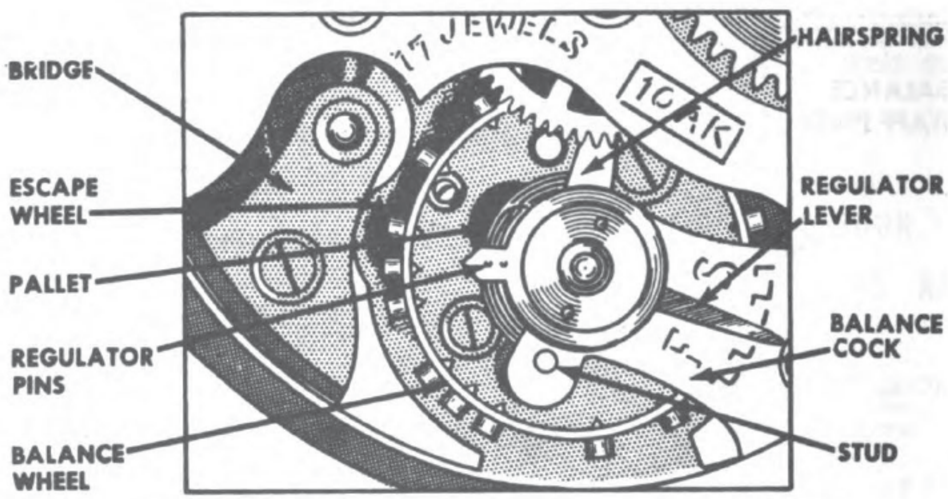



Figure 12. — Enlarged view of balance and hairspring assembly.

of an inner steel rim to which is fused an outer rim of brass. This type of rim is cut through in two places and carries screws around its edge. This kind of balance compensates for temperature changes both in itself and in the hairspring, and it can be adjusted to position. In the newer watches the balance wheel may be uncut and made solidly of Elinvar (taken from Elasticity Invariable), a nickel-steel chromium alloy which is almost insensible to temperature changes and therefore enables the watch to keep better time.

All American-made watches and clocks, including those used by the Navy, have the detached lever escapement. Watchmakers usually call it simply, the fork and pallet. It is shown

in figure 13. Let's take a minute or two now to study this picture closely. As an Instrumentman you will come to know the detached lever escapement intimately.

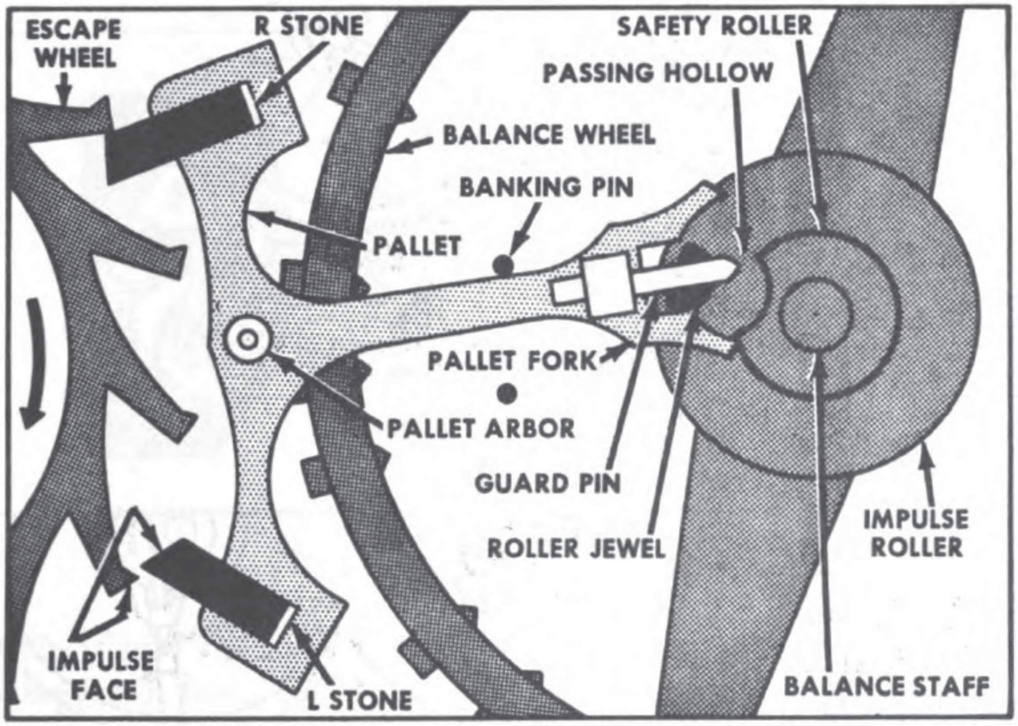



Figure 13.—Detached lever escapement (enlarged about 10 times).

When energy is stored in the mainspring, by winding, the train wheels begin to turn. This energy is carried from the barrel through the center, third, and fourth wheels to the escape wheel, turning the escape wheel in the direction of the arrow in figure 13. As the pallet receives energy from the escape wheel and rocks back and forth on the pallet arbor, the pallet fork moves the jewel pin (also called roller jewel). The jewel pin, being fastened into the impulse roller, moves the roller and causes the balance wheel to vibrate.

As the hairspring swings back and forth and makes the balance wheel oscillate, the roller jewel or jewel pin is carried back and forth across the center line *A-B* drawn through the escape wheel, pallet, and balance wheel (figure 14*A*). The jewel pin approaches the centerline, and when it enters the position shown in figure 14*A*, it enters and strikes the inside wall of the fork slot. During the passage of the jewel pin over the center-

line, the fork is moved in the direction of the arrow, (figure 14*B*) causing the *R* pallet stone to lock an escape tooth. (*R* is the receiving pallet; *L* is the let-off or discharging pallet.)

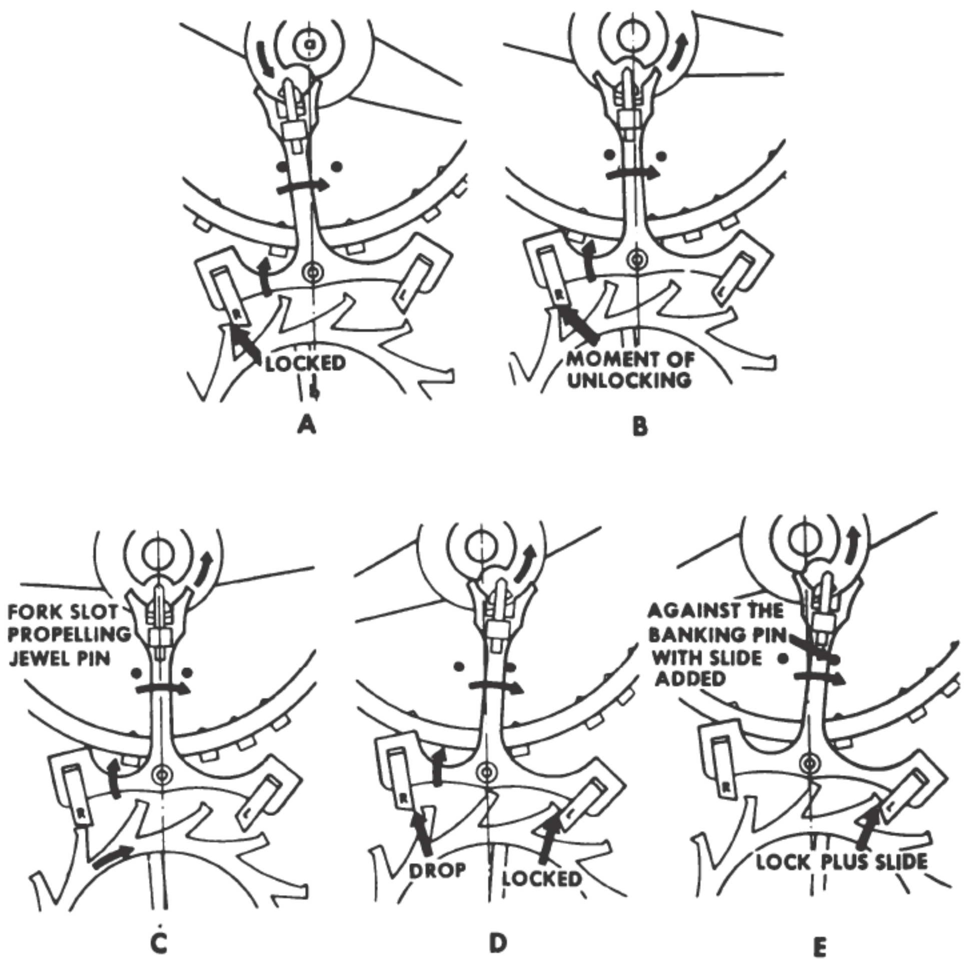



Figure 14A, B, C, D, E.—One-half of the escapement cycle.

At the instant of unlocking, the escape wheel is released, creating an impulse on the *R* pallet stone. This impulse pushes the pallet stone out of the path of the tooth (figure 14*C*). The impulse begins at the instant of locking. Now, instead of the jewel pin driving the fork, as was the case in the unlocking period, the fork pushes against the jewel pin thereby supplying the energy needed to keep the balance wheel in motion.

After the escape wheel tooth slides off the pallet stone, it travels a short distance, or drop, until another tooth locks on the opposite pallet stone (figure 14*D*). Actually, the pallet

moves slightly farther than the locking point because of the draw, which tends to hold the pallet against the banking pin. (Draw is the result of the force exerted by the escape wheel tooth on the locking face of the pallet stone.) The small additional distance moved by the stone on the tooth is called the

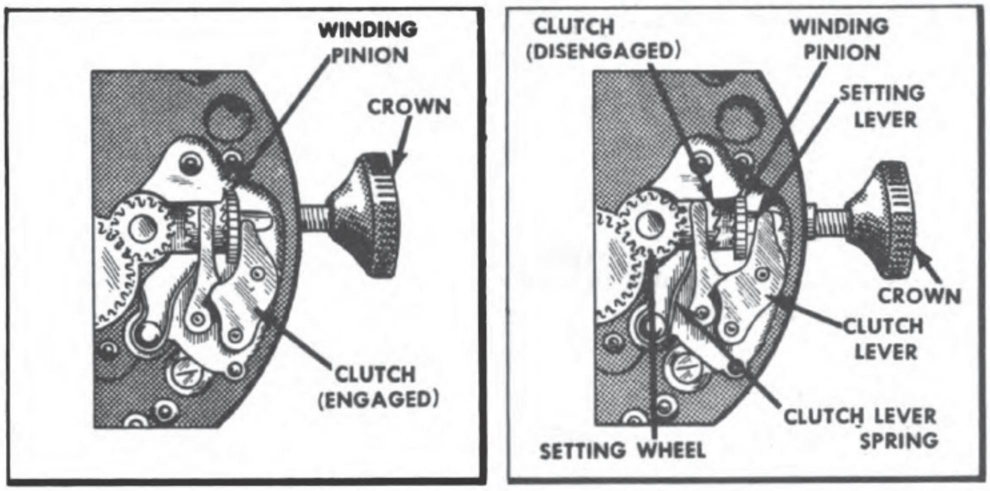



Figure 15.—The winding and setting mechanism.

slide (figure 14*E*). The balance wheel turns until the energy stored in it from the impulse is overcome by the tension in the hairspring, pivot friction, and air resistance. When the balance wheel and jewel pin, under the influence of the hairspring, return to the fork slot, the cycle of the escapement action will be repeated.

## THE INDICATING MECHANISM

The dial is graduated into hours, minutes, and seconds, and the hands tell the elapsed time. The center wheel, turning once an hour, holds the cannon pinion that extends through the dial and carries the minute hand. The cannon pinion turns an intermediate gear, and the pinion of that gear turns the hour wheel which is telescoped over the cannon pinion. If the watch has a second hand, it is usually mounted on the fourth wheel arbor, which projects through to the dial.

Winding the watch, or storing energy in the mainspring, is accomplished by a simple system of gears that revolve an arbor and winds the mainspring. Pulling the stem and crown out-

ward (figure 15) shifts a setting lever, clutch lever, and clutch wheel, engaging the clutch wheel with the setting wheel. The setting wheel is enmeshed constantly with the minute wheel, so pulling out the stem and crown permits the setting of the hands.

Now that you know what is inside a watch case and how the four major units of a watch are related to each other, we are ready to study the details of watch and clock repair in the Navy.

## QUIZ

1. What was the first method of measuring time, and at what period of history was it used?
2. What was the second timekeeper, and why was it an improvement over the first timekeeping method?
3. What invention, about the year 1500, made possible the modern pocket watch?
4. What invention in 1658 revolutionized the construction and accuracy of clocks?
5. What invention, about the year 1761, made it possible for navigation to become almost an exact science?
6. What are the four major parts of a watch?
7. Which unit of a watch is so important to its operation that it has been called the brain of the watch?
8. How many times does the barrel of a watch usually turn before the mainspring completely uncoils and the watch runs down?
9. How long does it take the barrel to rotate once, and how long does the modern watch usually run?
10. How many teeth has the escape wheel of a modern watch and how many turns does it make in an hour?
11. How is the energy of the escape wheel transmitted to the balance wheel?
12. What is *Elinvar*, and why is it used in modern watches?
13. Why are jewels used in watches and clocks?
14. What do the terms *R stone* and *L stone* stand for in the watch trade?
15. What is the purpose of the cannon pinion and how fast does it rotate?

## CHAPTER 3

# WATCH REPAIR TOOLS

### EXPENSIVE TOOLS

In 1776 the watch-jeweling tools from an English watchmaker's tool set were advertised for sale. The terms were 100 guineas (about $500) for the tools, and 100 guineas *for the sight of them.* Showing the tools, it was feared, would explain the art. That was the time of 7-year apprenticeships, when the secrets of watchmaking were closely guarded.

Today you need not pay to see watchmaker's tools. Each Repair Ship in the fleet and each Shore Repair Station has a Watch and Clock Repair Shop equipped with a set of modern tools. And, if approached tactfully, most watch repairmen on the beach will demonstrate their equipment to you. If you have mechanical aptitude and are willing to study and practice to develop skill in this trade, knowledge of its tools is readily available to you today. This chapter will introduce you to all the standard watch repair tools and their correct usage.

We cannot emphasize too strongly, however, that PRACTICE with these tools is essential for success. The tools themselves are simple. But it takes practice with them to create the SKILL

necessary to do the variety of repair jobs on watches and clocks of every type and make, and to do them accurately and rapidly. As a student watch repairman, you must acquire skill with tools before you can progress to the more advanced stages of the art. Old watchmakers have a saying: "I can't make a watchmaker out of you; the best I can do is to help you make one out of yourself."

Many of the special tools used in watchmaking are adapted from basic types used in other trades. Since the use of common tools is also described in Hand Tools, NavPers 10306, and in Use of Hand Tools, NavPers 10623, it will be well worth your while to read these books.

## THE BENCH

All Navy watch repair stations are equipped with watchmaker's benches. These are specially designed workbenches, 38 to 41 inches high, with trays, drawers, and boxes to hold the various tools in their regular places — out of the way when not in use, yet within easy reach when needed. They have a sliding drawer, about 10 inches below the desk top, which also serves as a convenient catchall. A comfortable seat with back rest, adjustable to a height of 14 to 16 inches according to the needs of the individual, is essential. Good lighting over the work area must be provided, either by a 60-watt frosted bulb in an adjustable metal shade, or two 25-watt fluorescent lamps with reflector. A piece of matt-finish white paper or cardboard about 50 inches square, fastened to the top of the bench with thumbtacks, gives a nice background for doing repair work. Figure 16 shows one of these benches.

## EYE LOUPES

If you have visited watch repairmen at work you have seen them using loupes (figure 17). Two types of these eyeglasses are generally used in the Navy: the 3-power size for general use and the 10-power size (stronger glass) for examining pivots, jewels, and mesh, adjusting balance springs, and similar fine

Figure 16.— Watchmaker's bench with lamp and adjustable seat.

work. There is no truth in the popular belief that loupes weaken the eyes. Of course, working for long periods with an extremely powerful loupe would tire one's eyes unduly. But the use of a proper-size loupe, under a good light and with both eyes open, is probably beneficial to eye muscles, just as exercise helps the other muscles of the body.

For examining jewel holes and pivots, where very small details must be observed, a ½-inch focus 18-power double lens, if available, can be used advantageously. This loupe is deeper in appearance than the others, so can easily be distinguished from them.

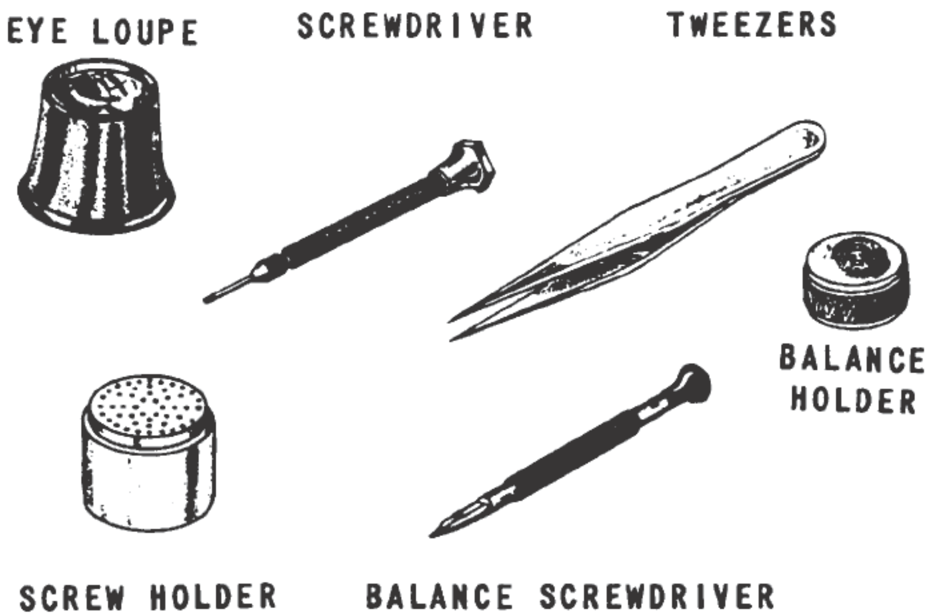



Figure 17.—The elementary hand tools for watch repair.

A watch balance or a balance assembly undergoing repair should always be supported on the bench in safety by a balance holder, one type of which is shown in figure 17.

## THE SCREW DRIVER

The standard watchmaker's screw driver (figure 17) is about 3 inches long. The blades are made from small diameter wire or rod of about four different sizes. The blade ends should be shaped with a reasonably long taper so they will not slip out of

a screw slot and mar its head when pressure is exerted. These screw driver blades should receive constant attention so as to keep them in a near perfect condition. The time used to file their bent or broken ends back to the original shape will prove to be time well spent. You can quickly reshape them on a No. 80 or No. 100 carborundum grinding wheel, if one is available. A screw holder, sometimes used by student watch repairmen, is shown in figure 17.

Watchmaker's screw drivers are handled differently from the large ones used by electrician's or machinist's mates. These small screw drivers are generally used in a vertical position, as

Figure 18.— Working with the screw driver.

shown in figure 18. Select a screw driver with a blade so ground that a slight wedging action will occur when the blade is pressed into the screw slot. The slight pressure which results will then support the screw.

The larger size, which has a blade of about 2.5 mm., is used mainly for operating place screws in and out of pillar plates and at other points where considerable pressure is needed. The smaller sizes are used for lighter work where a light, delicate touch is required. The balance screw driver (figure 17) is

about 4 inches long and is used for turning the small weight screws or the timing screws in balance wheels. Several kinds of balance screw drivers are in general use, including a telescoping type and a clamping type.

## TWEEZERS

The popular form of tweezers for general watch repair work is shown in figure 17. Tweezers are available in a great variety

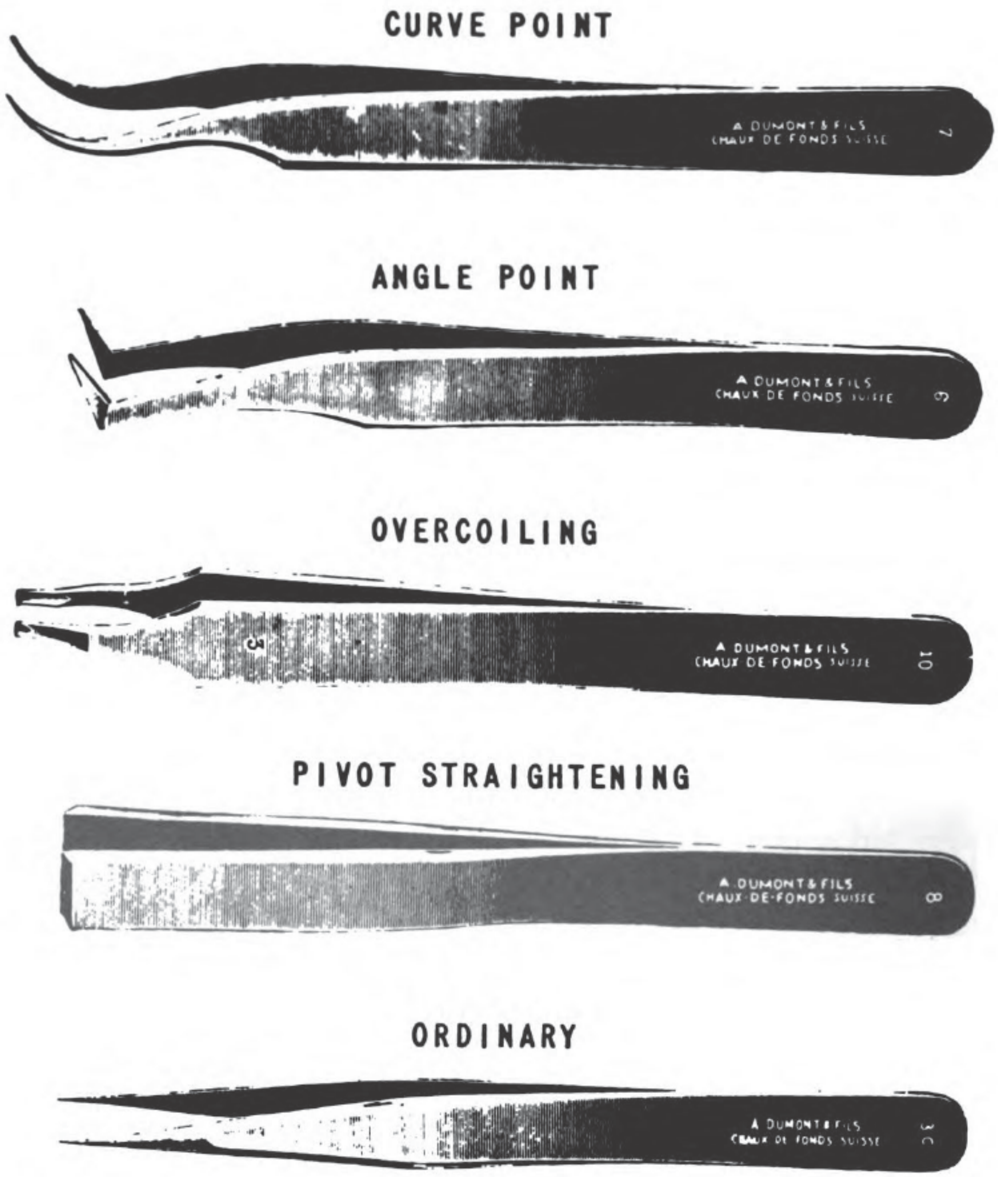



**Figure 19.— Some of the many types of tweezers. The type at bottom is popular for general work.**

of types for almost every conceivable job. Those of solid type, as shown in figure 19, will give best results for most watch repairmen. Among the 50 or more types available are brass tweezers for straightening pivots, locking tweezers for holding pallets, a very fine pair for hairspring work, and special curve-point tweezers for over-coil forming and other advanced work. Figure 20 shows the best way to handle tweezers in watch repairing operations.

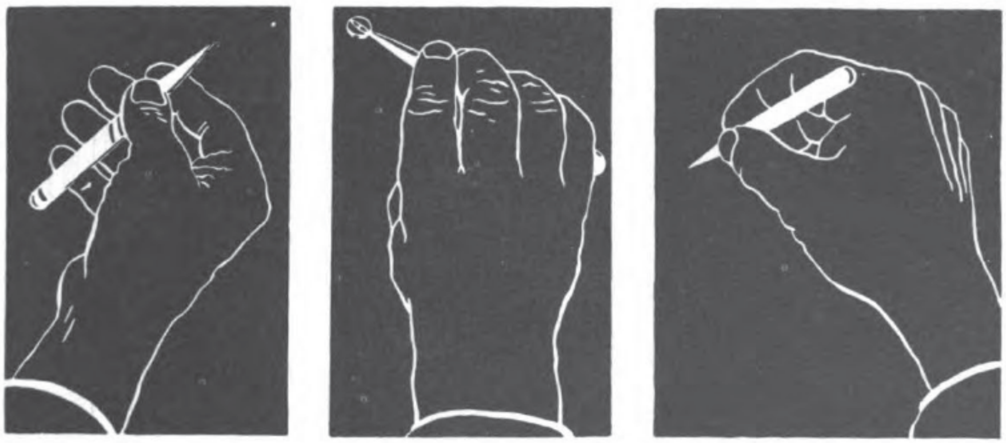


Figure 20.—How to use tweezers in watch repair work.

Tweezers need occasional testing and adjusting to keep them in good condition. If their points have become rounded on the edges from wear, or if they curl up when gripping a thin piece of metal firmly, such as a mainspring or a click, then the points should be trimmed down by rubbing them carefully on an Arkansas stone (a fine whetstone). Otherwise, they may allow a small watch part to snap out of them, resulting in damage to the part or possibly its loss.

## PLIERS

The watch repairman uses four or five pairs of pliers, each designed for a different type of work (figure 21). For general use the square nose-pliers will be preferred. For the more delicate work the repairman uses the narrow, tapered-nose pliers. For manipulating wire and such tasks the round-nose type is most suitable, while for holding finished surfaces, such

as in the removal of a cannon pinion, a pair of brass-lined parallel pliers is necessary.

A pair of optician's cutting pliers with thin edges will be found very useful when tightening cannon pinions. Most pliers of this type are furnished with an adjustable stop screw to eliminate the possibility of cutting the part in two. And

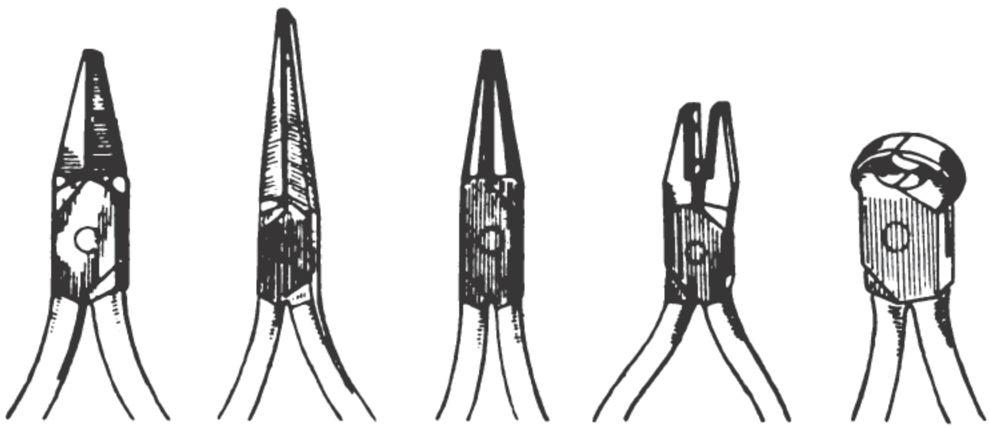



Figure 21. — Five kinds of pliers needed in watch work.

finally a pair of somewhat heavier nipper pliers will come in handy when holding and cutting small pieces of metal.

## THE MICROMETER CALIPER

For measuring diameters and thickness of metal parts, the metric micrometer caliper, commonly known as the micrometer, is an indispensable tool for the watch repairman. The size which measures up to 13 millimeters is most suitable. The conventional model is shown in figure 22, which also demonstrates the correct method of using it.

The barrel of the metric micrometer is calibrated in millimeters. When the part to be gauged has been placed in the micrometer, the visible number on the barrel (in millimeters) is noted. The rotating thimble, which covers the last millimeter division, has the decimal divisions of a millimeter engraved on

its outside. A full millimeter is indicated if the O mark on the thimble is in line with a millimeter mark on the barrel.

One complete revolution of the thimble is equal to half of one of the millimeters shown on the barrel. Therefore, if half a millimeter (0.5) is exposed after the 9 mark on the barrel, the marking on the thimble reads 5 and the decimal reading on the thimble is 0.05 millimeters; then the total reading (as

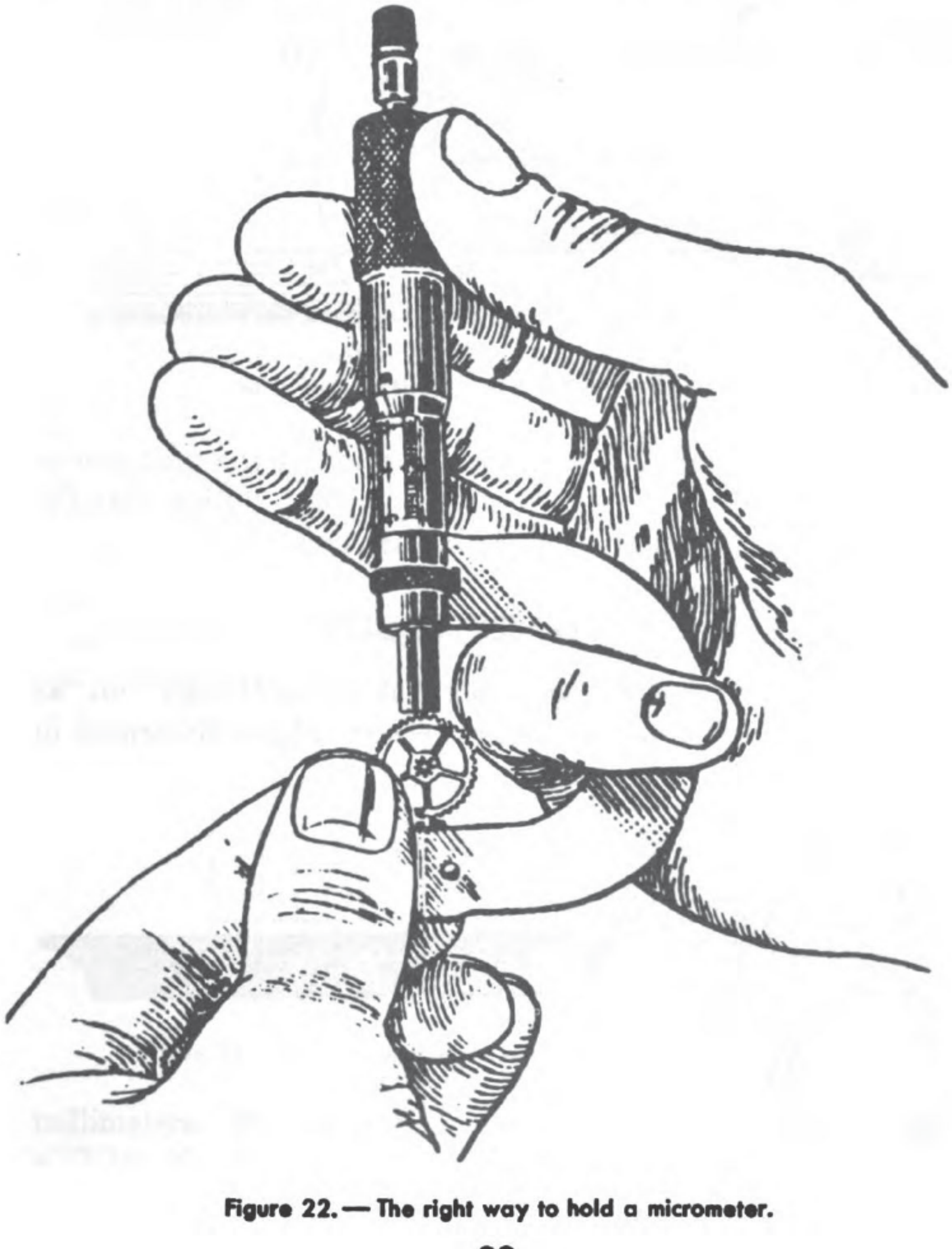


Figure 22.— The right way to hold a micrometer.

shown on the barrel in figure 23), is 9 millimeters plus 0.5 millimeter plus the 0.05 millimeter on the thimble, making a total

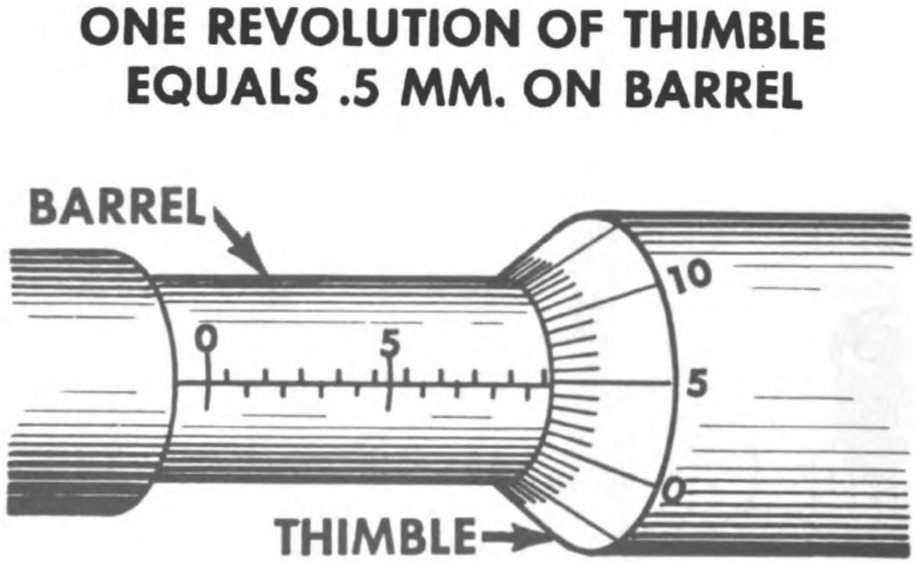



Figure 23.—Micrometer set to read 9.55 mm.

of 9.55 millimeters. For a full explanation of the micrometer caliper read *Use of Tools*, NavPers 10623. Notice also the vernier scale explanation as given in that book.

## THE VERNIER CALIPER

Another very useful measuring caliper, although not as accurate as the micrometer, is the vernier caliper illustrated in

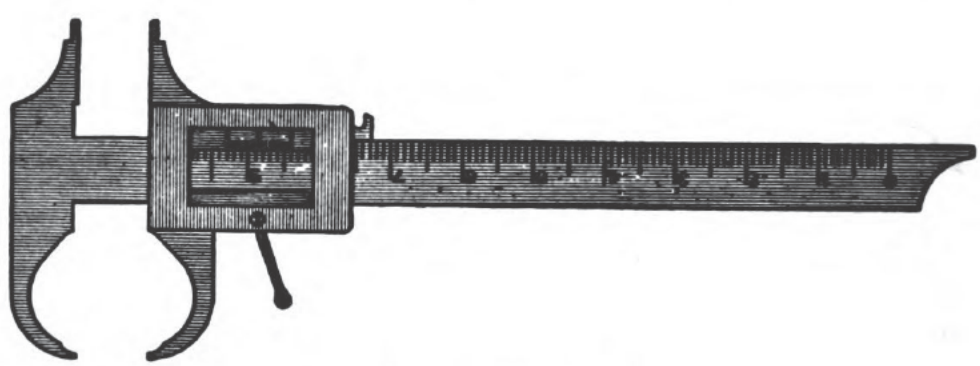


Figure 24.—A vernier caliper.

figure 24. Like the micrometer, it is graduated in millimeters, but it reads only to the tenth part of a millimeter.

The sliding jaw of this gage has a vernier scale added to it. There are 10 divisions on this sliding scale, in a space of 9 millimeters (figure 25). The two 0 marks coincide and the tenth

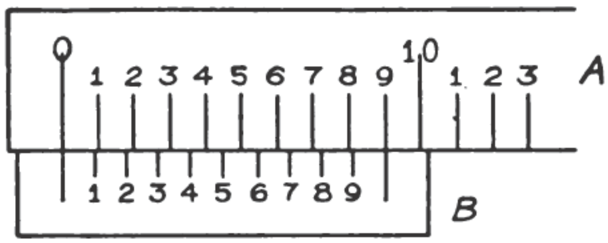



Figure 25.—A vernier scale showing 10 divisions on scale *B* equal to 9 divisions on scale *A*.

division on the sliding scale *B* coincides with the number 9 on scale *A*. If the sliding scale were moved to the right so that the No. 1 mark coincided with the No. 1 on scale *A*, it would then give a reading of 1 tenth of a millimeter. This indicates that the caliper jaws have been opened that much. If No. 2 mark on the sliding scale coincides with the No. 2 line on scale *A*, it would indicate an opening of 2 tenths of a millimeter, and so forth.

In figure 26 the 0 mark on scale *B* is beyond the 3 millimeter mark on scale *A*, giving a reading of something more than 3

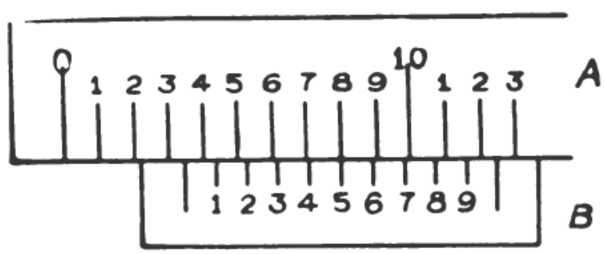



Figure 26.—Vernier showing reading of 3.5 divisions on scale A.

millimeters. But since the 5 mark on the sliding scale coincides with the No. 8 on scale *A*, a reading of 5 tenths of a millimeter more than 3 millimeters is indicated, or 3.5. In cases where

inside diameters are being measured with this kind of gage the thickness of the jaws, usually 2 millimeters, must be added to the gage reading.

## THE WATCHMAKER'S LATHE

The jeweler's or watchmaker's lathe is one of the watch repairman's most valuable tools. Since much of his work requires turning, grinding, and polishing small watch and clock parts, he should become a thoroughly skilled lathe operator as early in the game as possible.

A popular type of jeweler's lathe is shown in figure 27. It consists, essentially, of the lathe bed, headstock, tailstock, and T-rest. It is usually powered with a small 1/10-horsepower universal motor which operates on both direct and alternating

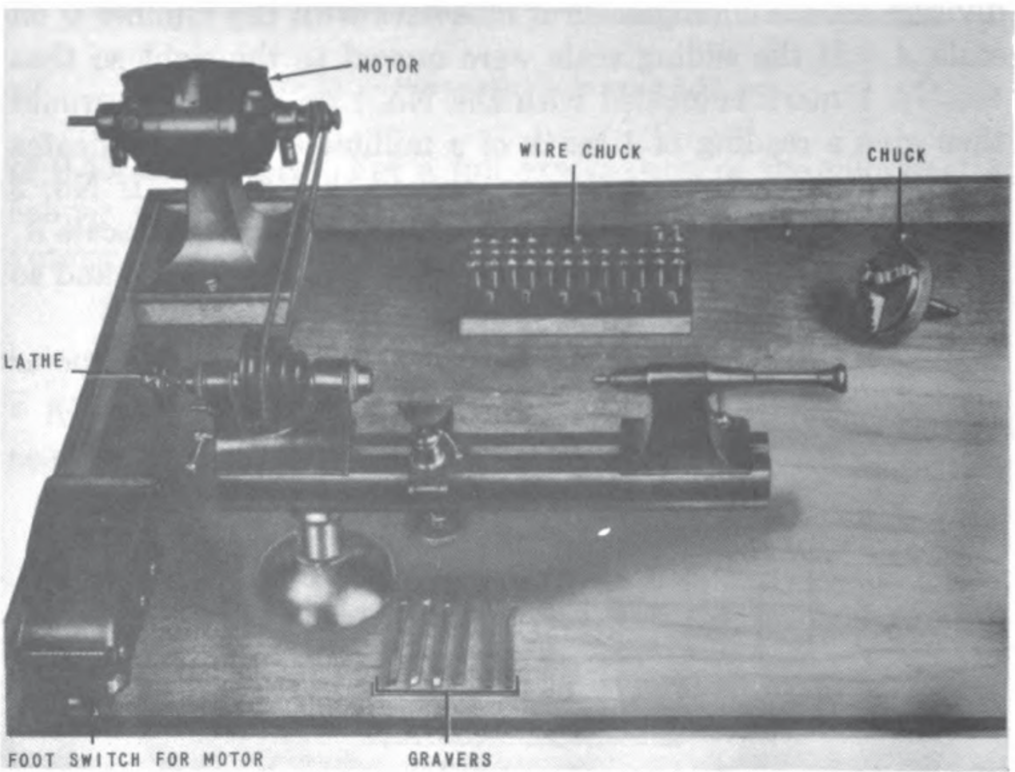



**Figure 27.— Watchmaker's lathe with gravers and wire chucks.**

current, and its speed is regulated by a foot-controlled rheostat located on the deck just below it. When the motor is operated

at low speed, a speed reducer or countershaft will be found extremely useful, since it prevents overheating of the motor.

This type of lathe is a precision instrument and should always be handled with great care. About every 12 months it should be taken apart, each of its bearings thoroughly cleaned and oiled with several drops of high-grade spindle oil, and then it should be reassembled and adjusted so that the headstock runs freely, but without play or endshake.

## GRAVERS AND CHUCKS

Hand gravers (figure 28 )are cutting tools, square or diamond-shaped in section, made of hardened steel and used to shape metals revolving in a lathe. They are held firmly by hand in

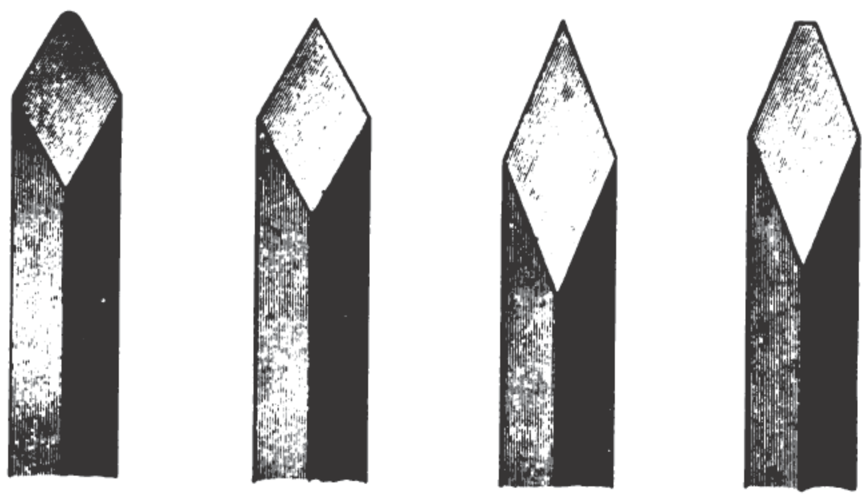



Figure 28. — Four common forms of gravers.

the correct cutting position (figure 29), while being moved slowly along the T-rest during the turning operation.

Gravers are made in a variety of sizes and shapes, depending on their intended purpose. For roughing out and for most turning work an all-round graver (shown in figure 28) is very suitable. Another type of graver, ground as at *C*, is suitable

for undercutting or finishing a corner. The point may be rounded off when heavy cutting work is to be done. Gravers must always be used with care; the point is very delicate and easily broken.

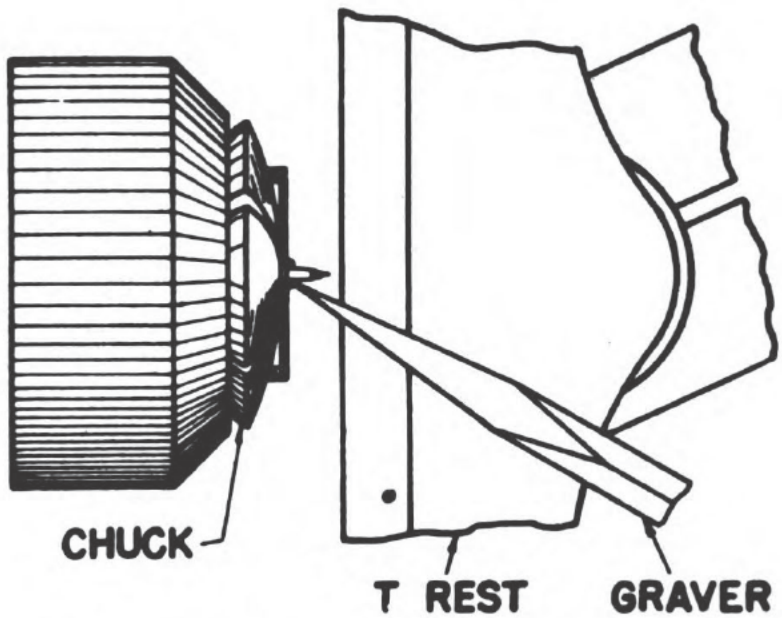



Figure 29.— Graver at correct cutting position on T-rest.

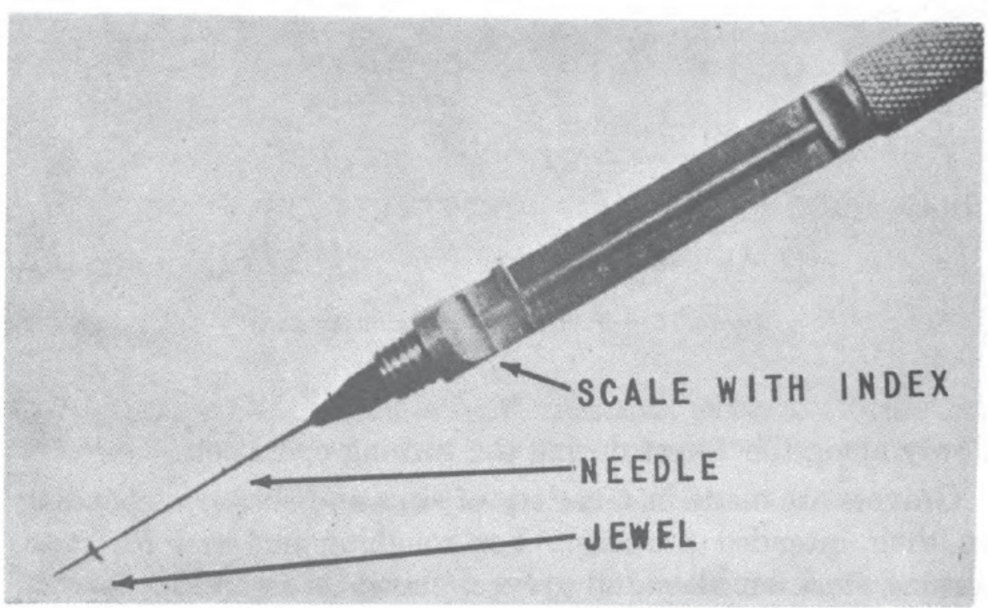



Figure 30.— This needle gage measures jewel-hole sizes.

Gravers in daily use must be sharpened frequently. To do this their cutting edge should first be whetted, using considerable pressure, on an India oilstone coated with a light machine oil, and the final finishing process is done on an Arkansas oilstone lubricated with sperm oil. All burrs or feather edges must be removed, otherwise bothersome scratches will appear on work. Skill in using gravers comes only with practice. Once you get started working on the jeweler's lathe and turning steel and brass watch parts, you will begin to learn the fine points of using this very important hand tool.

Wire chucks as used in watchmakers' lathes (figure 27) must have the same diameter as the piece, if they are to hold the piece true. The modern watch repairman should have at least several dozen sizes of wire chucks in order to accommodate the different diameters of the parts with which he must work.

## THE NEEDLE GAGE

Since jeweling is so important in this work, it is helpful to have a gage for quickly measuring the size of jewel holes. The needle gage, shown in figure 30, is handy for this purpose. The needle is tapered and the scale is graduated correspondingly. To measure the size of a jewel hole the jewel is placed on the needle and pushed back against the body of the gage. The position of the index on the scale then indicates the diameter of the hole.

## JEWELED PIVOT GAGES

The gages shown in figure 31 are very useful in fitting pivots when they must be measured. Their jeweled holes are graduated in size. The holes of the small gage vary in size by a quarter of a hundredth millimeter; the larger one has them graduated in half hundredths and the large gage is graduated in hundredths of a millimeter.

## THE STAKING TOOL

The shaft on which the balance wheel of a watch is mounted is called the balance staff (figure 32). The operation of fastening

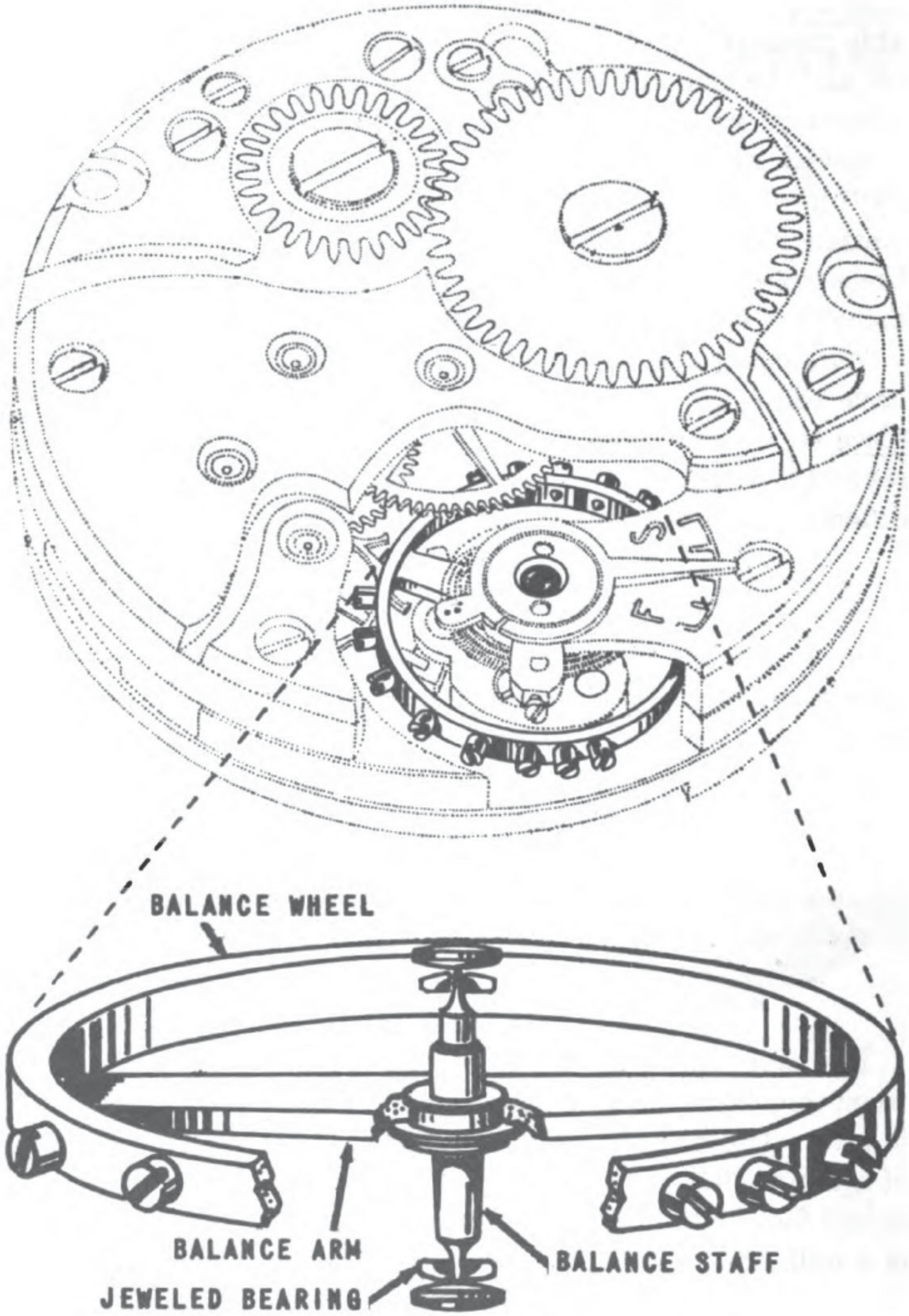



**Figure 32.— Cutaway view of balance staff fastened to balance arm.**

the balance wheel rigidly to the balance staff is known as staking. The staking tool, shown in figure 33, was originally designed to aid new watch mechanics in staking work; it has since become

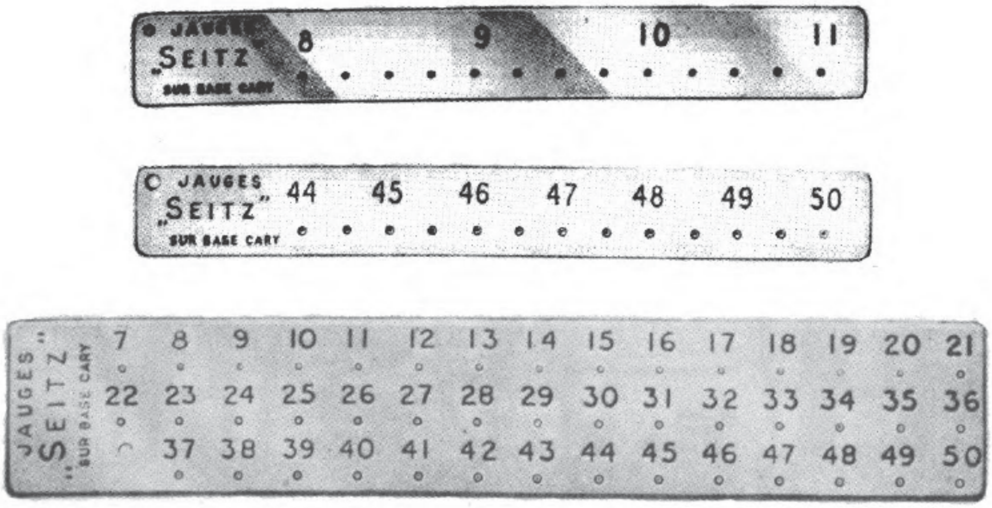



Figure 31. — Jeweled pivot gages for fitting pivots.

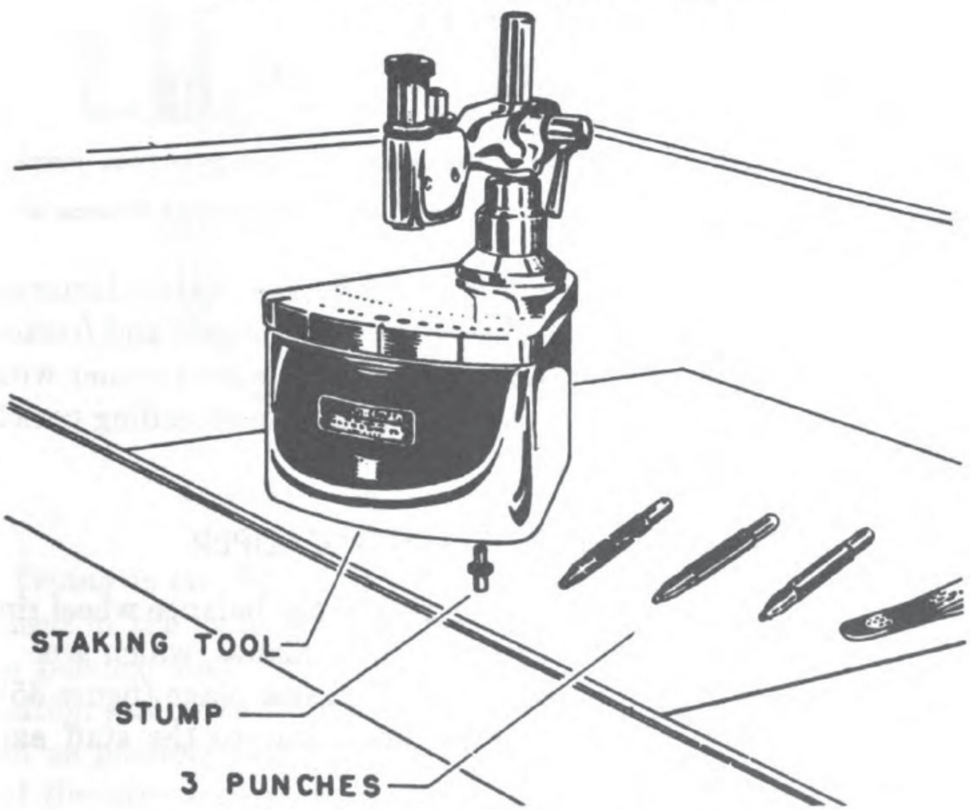
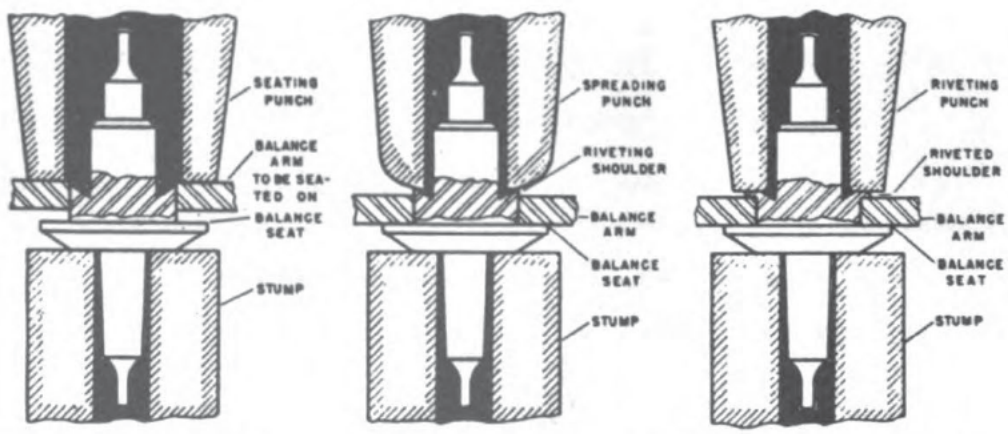



Figure 33. — The staking tool, three punches, and a stump.

extremely valuable to repairmen for doing staking and a great variety of other operations.

In staking a standard rivet-type staff, a *seating punch* is used to force the balance arm down onto a staff held in proper position on the staking stand by a small holder or *stump*. (See figure 34.) The *spreading punch*, of a size having a smaller diameter opening, is used to spread the riveting shoulder. Then, by light taps of a brass hammer, the riveting shoulder is flattened out with the flat-faced *riveting punch*. That completes the staking operation.




USE OF SEATING PUNCH　　USE OF SPREADING PUNCH　　USE OF RIVETING PUNCH

Figure 34. — Steps to be followed in staking a standard rivet-type balance staff.

Besides the standard rivet-type staff, the watch factories make shafts of types known as *top groove*, *side groove*, and *friction fitted* shafts. The staking tool is used in a similar manner with all of these, except that with some of them the spreading punch operation is not necessary.

## THE BALANCE TRUING CALIPER

Balance truing involves the bending of the balance wheel rim until it meets the requirements of a true balance, which are:

1. All parts of the rim must lie in the same plane (figure 35).
2. The entire rim must be perpendicular to the staff axis (figure 36).

During the truing operation the balance is held in the balance truing caliper. The screw-type truing caliper, shown in figure 37, is used by Navy watch repairmen. An adjustable index,

mounted on a sliding bar, fastened to the frame, serves as a fixed reference for this adjustment. The truing operation is done in two parts: (a) truing in the flat, and (b) truing in the round.

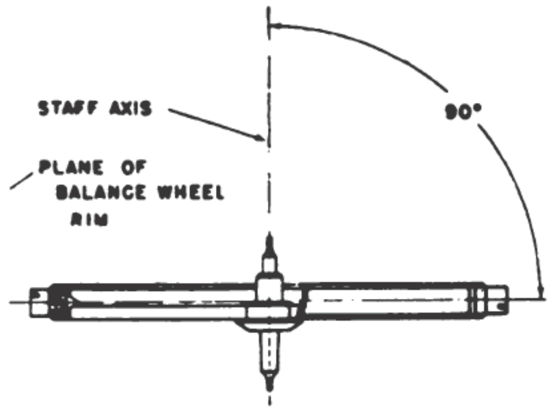



Figure 35. — Balance wheel with all parts of the rim in the same plane.

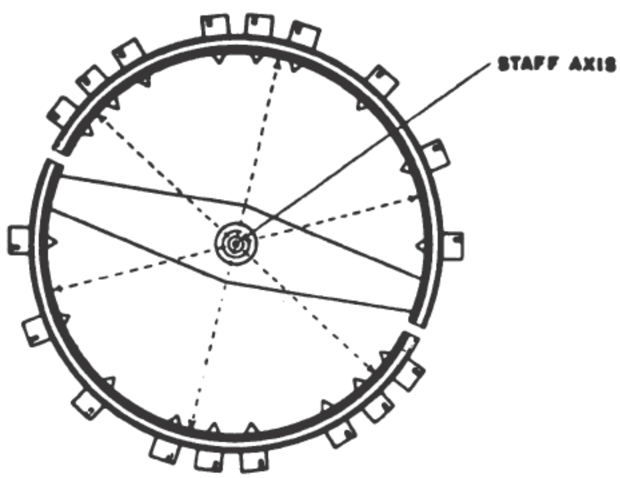



Figure 36. — Rim perpendicular to the staff axis.

*Truing in the flat.* — To accomplish this the balance wheel is placed in the calipers with the cones of the pivots supporting the balance staff. The next step is to adjust the index to a position *just above the balance arm* and as close to the end of the arm as possible (figure 38). Fix the space between the index and the arm accurately in mind, then turn the balance wheel until the other arm is directly under the index. The space between the index and either arm must be exactly the same. If a variation is noted, the arms must be adjusted until they

are equal in height. This adjustment is done by taking hold of the rim firmly with thumb and forefinger and gently forcing the arm up or down, as required.

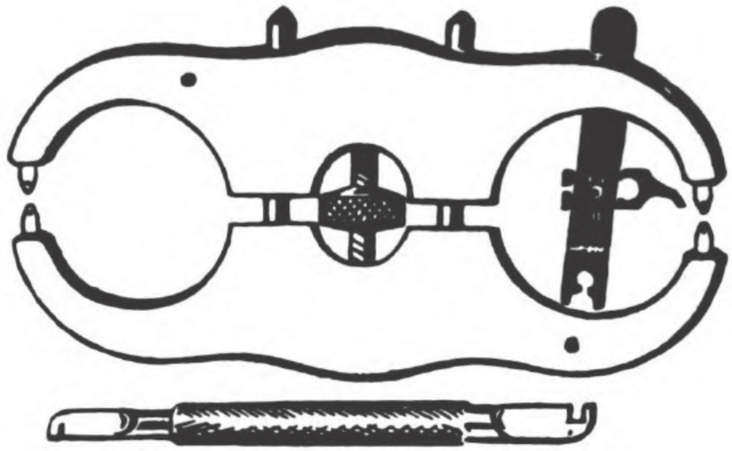


Figure 37. — Screw type caliper and rim wrench.

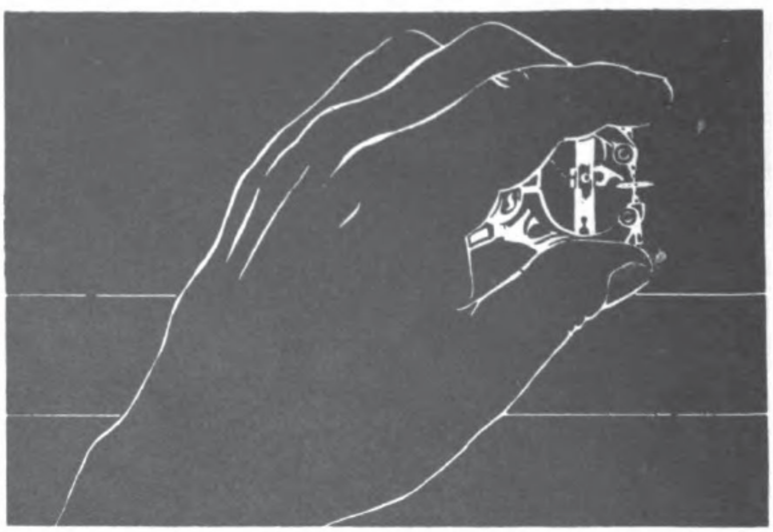


Figure 38. — Holding the truing caliper. Truing in the flat.

Now readjust the index to a position *directly over the rim* at the end of the arm. A narrow slit of light will be visible between the index and the rim when the calipers are held in the proper truing position. Rotate the balance with the side of the right forefinger, noting any variation in the width of the slit of light. Any increase in the light space indicates a downward bend in the rim. The thumb and forefinger are then used to apply pressure at the proper point at the rim, until the light space around the rim is uniform.

*Truing in the round.* — This consists of bending the rim of a balance wheel until it conforms to the third condition stated above, namely, the entire rim must be concentric with the staff axis. To perform the operation, readjust the index to a point *just above the outside surface of the rim.* Then slowly rotate the balance, working from the end of the arm to the cut (on bi-metallic balance wheels). Any change in the index clearance indicates a bend in the rim. Eliminate each bend as it appears, using a rim wrench for the purpose.

The rim must not be twisted during the truing operation. When completed, the entire rim must be perpendicular to the balance arms.

## THE POISING TOOL

After the balance wheel has been trued it must be poised, since an out-of-poise balance wheel will affect the ability of a

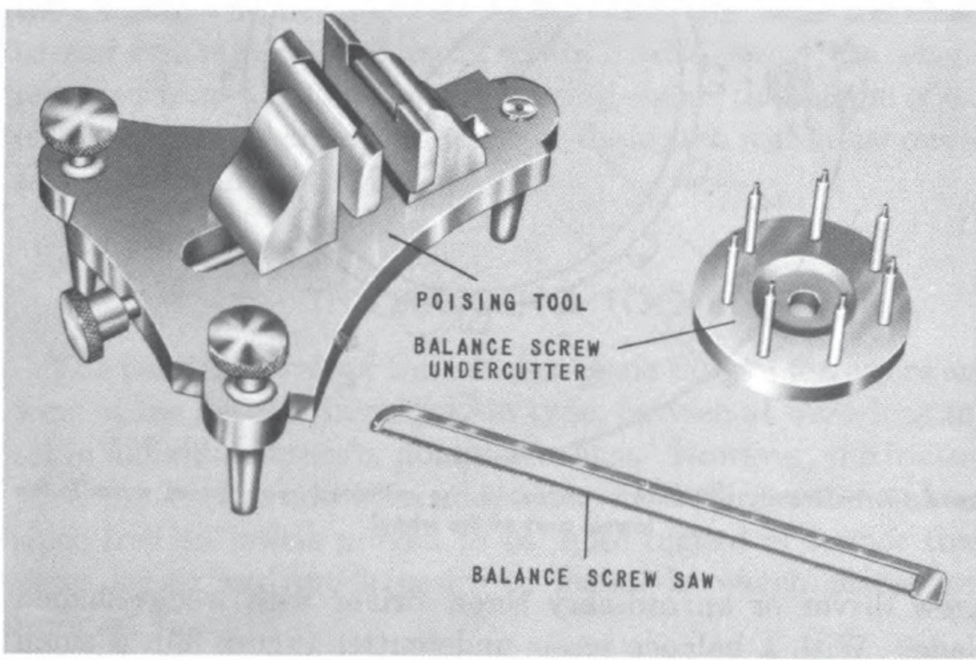



**Figure 39. — Poising tool with balance screw undercutter and saw.**

watch to keep good time. Poising is done with the rollers attached to the wheel, but with the hairspring removed.

The balance wheel is placed in the poising tool (figure 39), the jeweled knife blades of which are adjusted to support the

extreme ends of each pivot. This allows the balance wheel to be suspended freely so that the only force acting on it is the force of gravity. Any movement of the balance around its balance staff axis then will be due to gravity acting on the various parts of the balance. A perfectly poised balance wheel will revolve slowly; but if it is an unpoised balance, the heaviest part of the rim will turn to the lowest point. If one screw, as No. 13 in figure 40 is the apparent heavy point, it will be drawn by gravity down to the lowest part of the wheel. When the heavy screw is located, it can be removed by using the balance

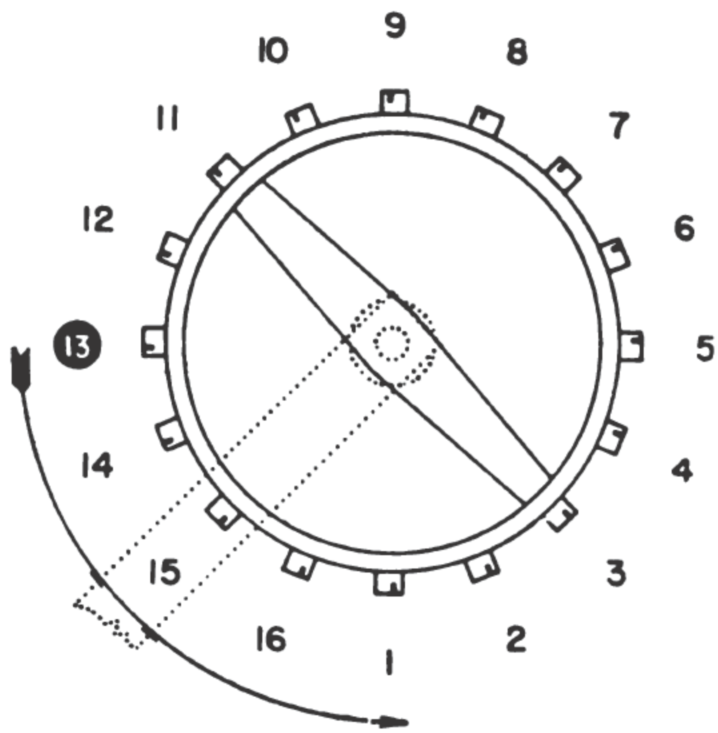



Figure 40. — Gravity will draw screw no. 13, the indicated heavy point, down to the lowest part of the wheel.

screw driver or an ordinary screw driver with wedge-shaped blade. With a balance screw undercutter (figure 39), a small amount of metal is removed, and the screw is then replaced. If after replacement of the undercut screw the opposite screw appears heavy, too much metal has been removed in the undercutting of the original screw. The opposite screw is then undercut, using care not to remove too much weight from it. The balance is then checked for poise.

When a wheel has been placed very nearly in poise, a fine balance screw saw (figure 39) may be used to finish the operation. Only very small amounts of weight should be removed that way, with care being taken not to spoil the screw's shape or appearance.

When the balance is heavy at a *mean-time* screw (small screws used for timing), weight may be removed from the screws on each side of it. Mean-time screws are never undercut during the poising operation.

During the undercutting operations a certain amount of weight has been removed from the balance wheel. Since an appreciable change in the weight of the balance will affect the rate of the watch, it may be necessary to restore any considerable amount of weight removed by adding a pair of timing washers to any two opposite screws. These washers come in a variety of sizes. A pair of one-minute timing washers added to the balance wheel of one well-known make will cause the watch to run one minute slow in 24 hours. Likewise, if the weight removed from a balance during poising equals the weight of one of these timing washers, the rate of the watch will be increased about 30 seconds in 24 hours.

## THE JEWELING TOOL

The bearing jewels of the watches made up to a few years ago were of the bezel or burnished-in type, beveled at the edges and set in individual brass or gold mountings. However, the friction jewel process has now been adopted by all leading watchmakers, since friction jewels proved to be more rugged in service than bezel jewels and much easier to install in watch plates and bridges.

Balance staff jewel bearings always consist of two-hole jewels, each backed with cap jewels, also called endstones. Figure 41 shows the relative position of these jewels. The shape of a jewel and its jewel hole is extremely important to the performance of the watch. More detailed information on watch jewels will be given in chapter 4.

The friction jeweling tool (figure 42) consists of a lever device, a set of reamers, a set of pushers, and an assortment of stumps. Before the jewel is inserted, the hole must be reamed out. The

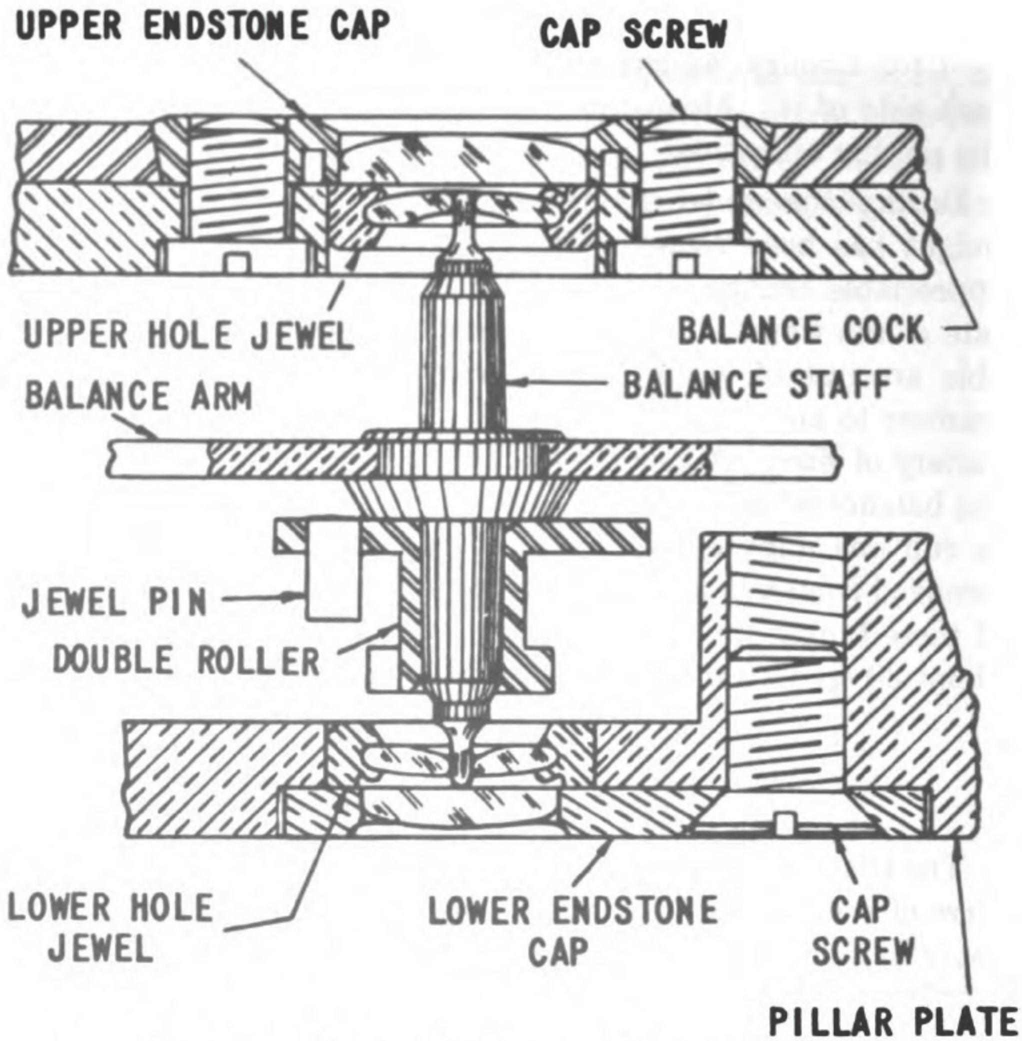



Figure 41. — Cross section view of balance staff, hole jewels, and endstones.

precision-gaged reamers are of the self-centering type numbered to correspond to the jewel diameters. Actually, they are 0.01 mm. smaller in diameter than the jewel. The jewel can then be pressed to any required depth by means of the leveling lever. The depth to which the jewel is inserted is controlled by a micrometer stop or depth gage.

Figure 43 shows the first step in the friction jeweling process. After the plate hole is reamed to size, any burr at the edge of

the hole is removed with a countersinking tool. The proper jewel, corresponding with the reamer number, is then selected. The pivot hole size is checked with the balance staff pivot diameter for sideshake. If the face of the jewel is to be flush with the plate or bridge, a pusher larger in diameter than the

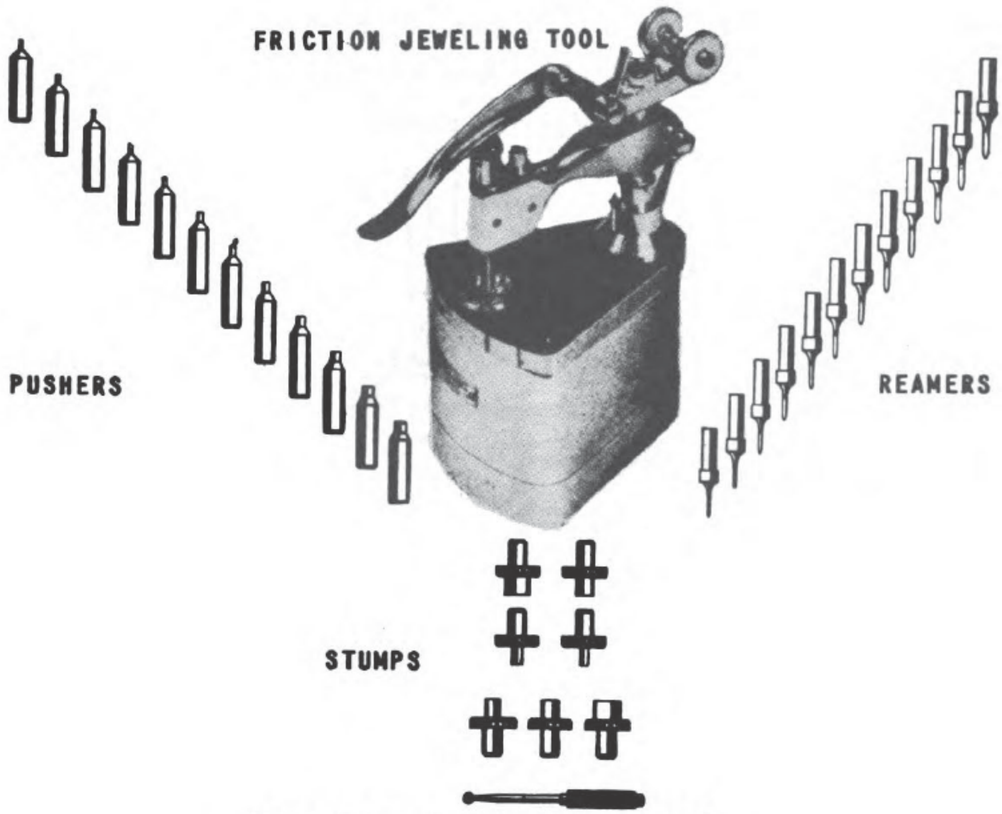



Figure 42. — The friction jeweling tool.

jewel is selected (figure 44). If the jewel face is to be inserted below the plate or bridge, a pusher of smaller diameter than the jewel is used.

When a broken jewel is to be replaced, a pusher is inserted in the jeweling tool and the micrometer stop adjusted to its depth. The cracked jewel is then removed with a smaller diameter pusher, the hole reamed to the desired size, and the burr removed. The correct size of jewel is then selected, corresponding with the reamer number, and inserted to the correct depth as determined by the micrometer stop.

It will be evident, even from this brief description, that friction jeweling is a most important advance in watchmaking.

Because of it, watches today are simpler, less costly to make, more accurate in performance, and very much easier to repair.

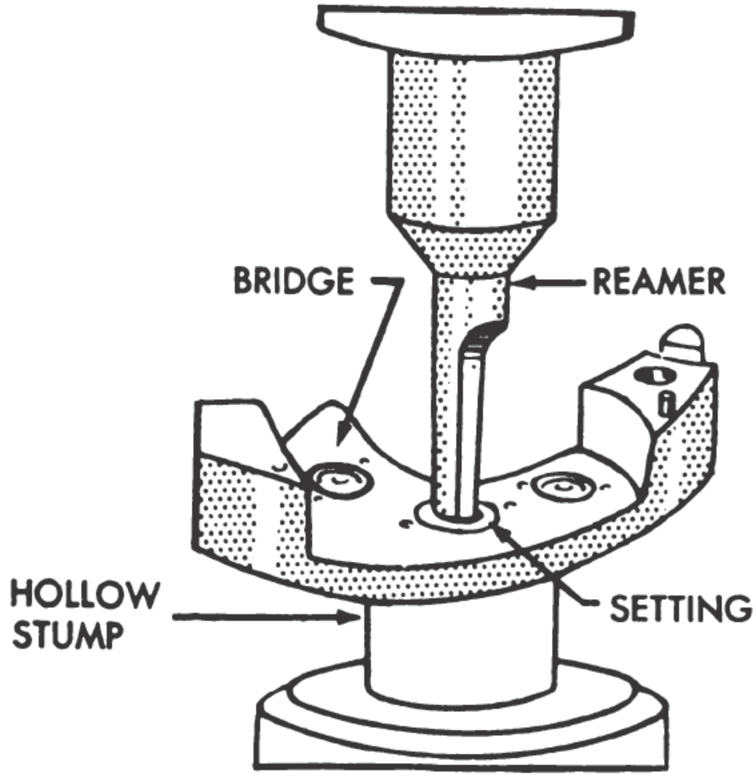



Figure 43.— Reaming hole in a watch bridge with self-centering reamer.

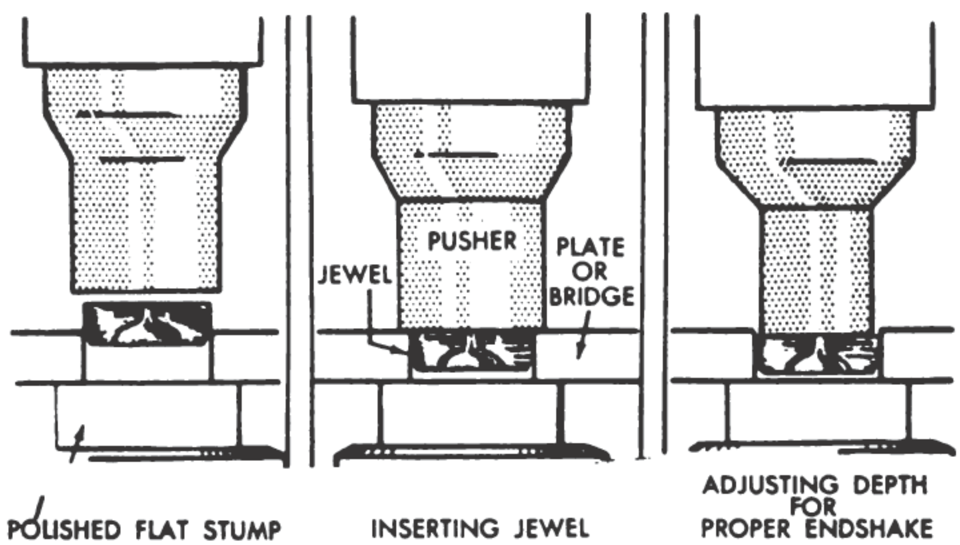



Figure 44.— Steps in using the jeweling tool.

## SUMMARY

The tools that have been described in this chapter are all used regularly by the watch repairman. As explained above, he employs a special manner of handling each tool, depending on its shape and purpose. In disassembly and assembly, the screw drivers, tweezers, and holders help him spread the individual watch parts out on the bench so that he can clean, oil, and repair each part. He uses the jeweler's lathe with a graver properly selected and held, to turn a new balance staff. He uses the small micrometer to mike its correct size down to one thousandth of a millimeter. He installs the staff with the help of the staking tool.

The needle gage and the jeweled pivot gage are essential in measuring jewel hole and pivot sizes. The balance truing caliper, the poising tool, and the jeweling tool will help tremendously in making other repairs and in balancing and assembling critical parts so as to provide a perfectly adjusted and expertly repaired watch. Without these tools, the repairman could do none of these things. With them, he performs all these operations with ease.

Skill in using watch repair tools will come with experience at the bench. Try for an opportunity to work in your ship's watch repair shop. There skilled men will show you how to use these tools. They are ready to teach you, in the true Navy tradition, the practical things you will need to know about watch repairing tools to qualify for Instrumentman.

## QUIZ

1. Which sizes of eye loupes are commonly used in watch repair?
2. In what position are screw drivers usually held when being used in watch repair?
3. Which tool is generally used by watch repairmen to measure diameters and thicknesses accurately?
4. What is an Arkansas stone?
5. What is a needle gage, and for what purpose is it used?
6. Why does the watch repairer use the micrometer caliper more frequently than the vernier caliper?

7. Which type of plier is most commonly used in watch repair?
8. How can the speed of a jeweler's lathe be reduced without overheating the motor?
9. What is staking?
10. What is truing in the flat?
11. What is truing in the round?
12. What is poising?
13. What are the component parts of the friction jeweling tool?

## CHAPTER 4
# CLEANING AND OILING WATCHES

*"Hereby I learned here, not to despise,*
*Whatever thing seems small in common eyes."*

When Edmund Spenser, a great English poet of the sixteenth century, wrote this couplet he was telling the story of a small swordfish which attacked and killed a huge sea animal, probably a whale. With these lines he tried to impress on all peoples the value of small things. He did not know watchmaking; in fact, pocket watches had not been invented at that time. But had he been a watchmaker, he certainly could have mentioned, as a fitting example of his thinking, the cleaning of watches. To most people, the cleaning of a watch is a very unimportant matter. Yet thousands of fine watch repair jobs have been spoiled after a few months in service simply because the cleaning operation was slighted and considered unimportant. In reality, cleaning is one of the most important parts of watch repair.

If everyone who wears a watch could look through a microscope just once to see the dust and dried oil accumulated on the moving parts of his watch, he would realize the need for a periodic cleaning. Unfortunately, watch owners never seem to learn that pivots covered with thick, gummy oil cause wear on

the parts; the friction decreases the power and makes the timepiece show an erratic rate. All watch repairers have not realized the importance of cleaning, either.

The balance wheel plays a vitally important part in the watch performance. It swings 18,000 times an hour, or 157,680,000 times a year. If it were moving in one direction, in the course of a year it would travel about 4,000 miles. It is obvious, then, that every watch needs a good cleaning at least every 12 months if its operating condition and accuracy are to be maintained.

Two methods of cleaning watches are in use today, the machine method and the hand method. The Navy prefers the machine method. Cleaning with the watch machine is faster and easier than the hand process. Tests have shown the superiority of the machine method for cleaning such parts as pinions, hairsprings, mainsprings, and pallets. With this method, all the parts of the watch, both large and small, may be cleaned without additional effort. Furthermore, this method makes it possible to clean a watch movement thoroughly without the use of sawdust for drying the parts, eliminating the possibility of a piece of foreign matter being left in the watch to cause trouble later.

## THE MACHINE CLEANING METHOD

The cleaning process begins with disassembly of the movement. All parts must be completely separated, so that the cleaning solutions can reach every piece, such as worn, bent, or broken pivots and cracked or broken jewels. The stem work should be removed from the pillar plate and the mainspring taken out of the barrel. Any old, thickened oil sticking to the jewels should be removed with a pegwood stick.

Cleaning machines, such as the one shown in figure 45, are equipped with wire mesh baskets, subdivided so that the large and small parts may be kept separate. The heavier parts, such as the plate and bridges, are placed in one compartment (see figure 46); the train wheels, winding and setting parts, dial train, pallet, and all other smaller parts are placed in another compartment. The balance assembly is placed in a compartment by itself. The mainspring is removed from the barrel and

cleaned by hand by wiping carefully with a soft rag, a strip of chamois, or watchmaker's no-lint paper soaked with cleaning solution. Take great care not to distort the shape of the spring. (If the mainspring is bent or "set", always replace it with a new one.)

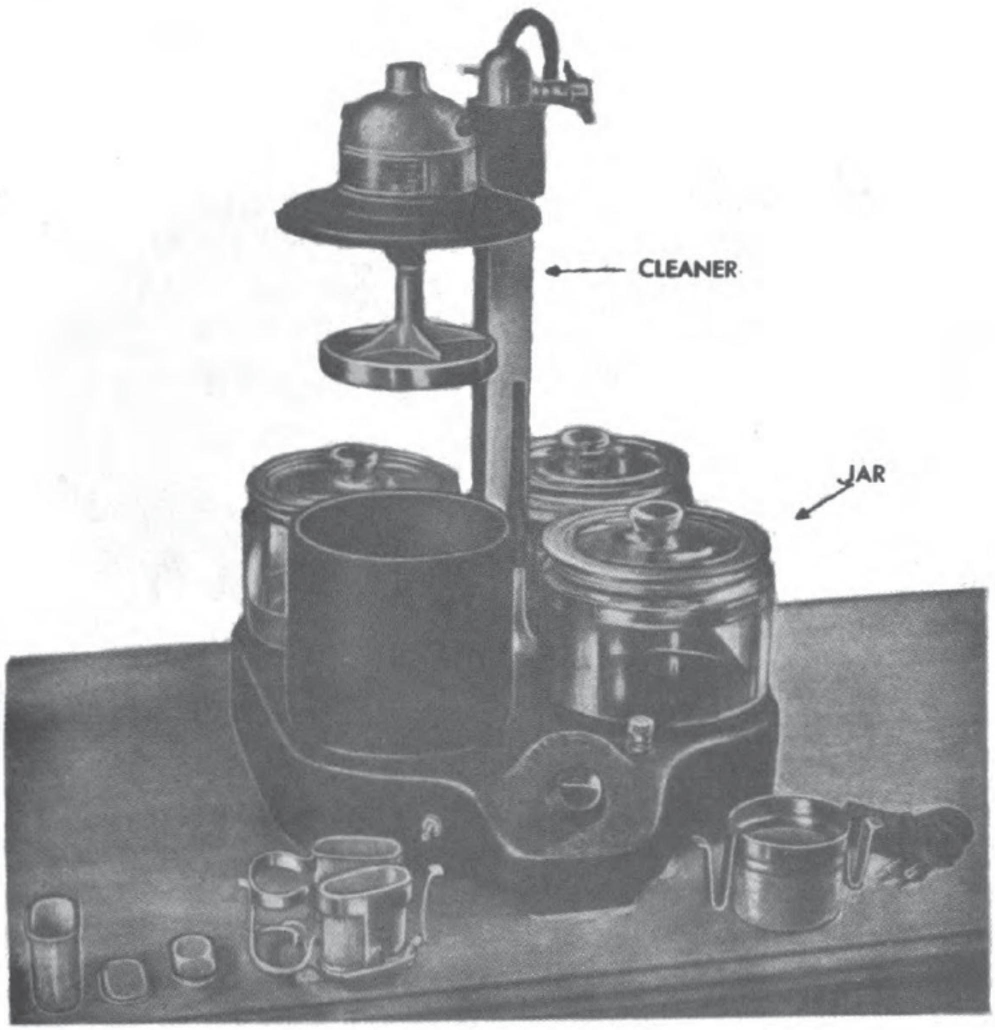



Figure 45.—L. and R. master watch cleaning machine.

The basket of the cleaning machine is immersed in different solutions in this order:

1. Cleaning solution (jar No. 1).
2. First rinse (jar No. 2).
3. Second rinse (jar No. 3), same solution as in jar No. 2.

You should use an approved watch-cleaning solution, such as L. and R. Mfg. Company, NOFOME Waterless Cleaner No. 1, or

similar cleaning solutions supplied by the Peerless Company and the Zenith Company. These solutions are nonflammable liquid degreasers and are excellent solvents for oils, fats, greases, and waxes. However, watch parts should *never* be immersed in them longer than the period prescribed. Prolonged immersion will result in etching of the parts.

The approved rinsing solutions are clear alcohol-base, volatile, nonexplosive solvents, which leave practically no residue when evaporated to dryness.

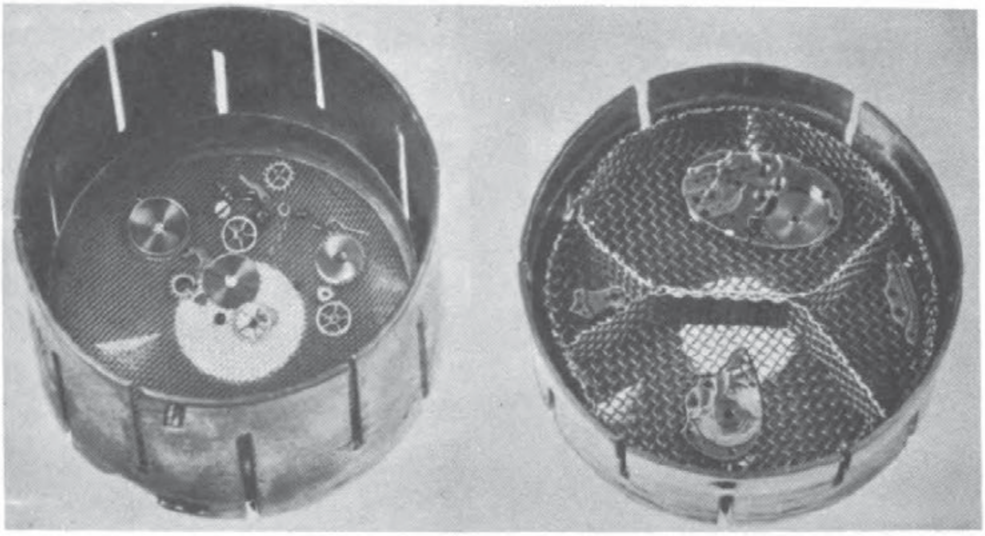


**Figure 46.— Watch parts in separate basket compartments.**

The basket of the cleaning machine is rotated in the cleaning solution (jar No. 1) for 2 minutes. Rotation should be stopped two or three times during this process so that any air trapped in the basket may escape. This precaution should be observed with each rotation, because air remaining in the basket will prevent the solution from doing its work. Excess solution is expelled by raising the basket above the solution in the jar, after the 2-minute rotation period, and spinning the basket slowly for about 30 seconds. The same process is repeated in the No. 2 and No. 3 jars, which contain rinsing solution. After the second rinse, the basket is rotated in the electrically operated drier for several minutes, so that any trace of the rinsing solution will be expelled and the drying process completed. When the rinsing solution in jar No. 3 begins to show discoloration, it

should be transferred to jar No. 2, and replaced with clean rinsing solution. The solution which was in jar No. 2 should be thrown away.

When drying is finished, the basket is unfastened and the parts are carefully removed. The cap jewels should be removed in cleaning. Remove them now, one at a time, replacing them in their proper position after the cleaning operation. A sharp piece of pegwood is run through all the jewel holes to remove any foreign matter that was not washed off in the machine, and the cap jewels are rubbed thoroughly to make sure that they are clean. Pivots may be pressed into a piece of pith to remove any gummy oil residue. In general, all the watch parts should be carefully examined for any impacted dirt or rust that might have escaped the cleaning operation. If any is found, it can usually be removed with a soft hand brush. The movement is now ready for reassembly.

## THE HAND CLEANING METHOD

If the repair ship's supply of watch cleaning solution should become exhausted, you may have to use the hand-cleaning method.

When watches are cleaned by the hand method, all parts of the movement except the dial, hands, mainspring, and case should be thoroughly cleaned in a cleaning solution. The parts are strung on dip wires (see figure 47) and soaked in the cleaning solution. The balance jewels and cap jewel are removed, and the plate, bridges, balance cock, setting levers, and other large parts are hung together on one dip wire. (Laying the jewels out in proper order on a small covered jewel tray will make it easier to replace them later.) The main train wheels, dial train wheels, clutch, winding pinion, crown, and ratchet wheel are strung on another wire, and the balance assembly is placed on a wire by itself.

In hand cleaning, the parts are soaked in a rinsing solution of high grade benzine or naphtha for about 10 minutes (the exact time depending upon the strength of the solution), then removed and allowed to dry. They are then dipped several times into a degreasing solution, such as cyanide of potassium.

The larger parts are brushed vigorously with a small, soft brush; the smaller parts are swished around in the solution for a few minutes. All the parts should be rinsed in warm soapy water, immersed in grain alcohol, then transferred from the dip wires to sheets of watchmaker's no-lint paper and allowed to dry. Rub each part separately with linen cloth to complete the drying operation. (Old-time watch repairmen always dry watch parts in boxwood sawdust kept warm continuously for this purpose.)

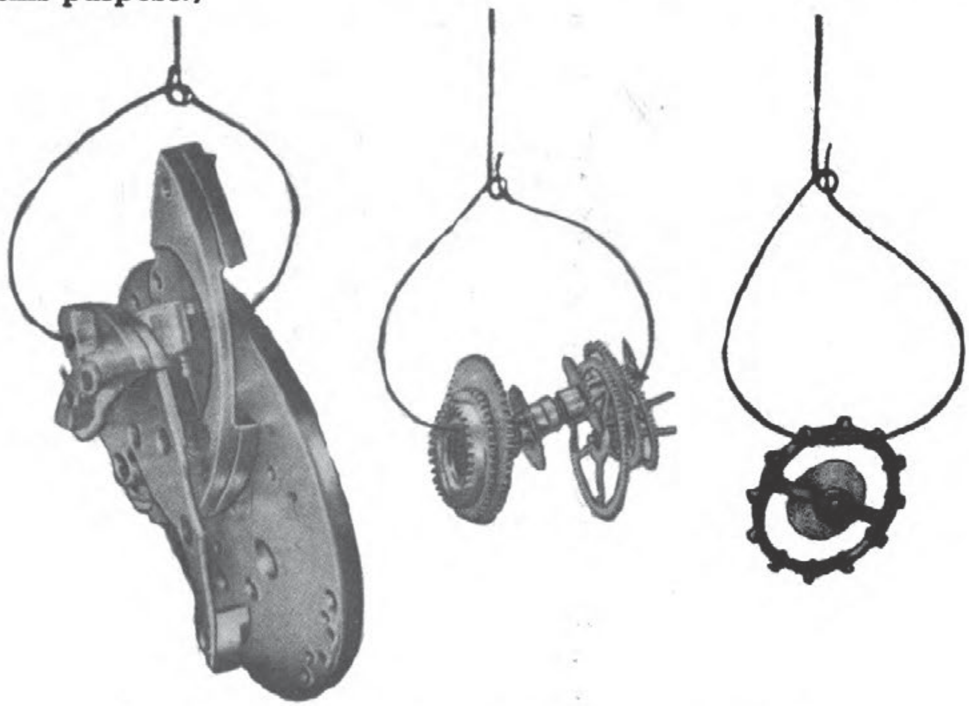


Figure 47.— Watch parts strung on dip wires for cleaning.

The parts are then brushed carefully with French chalk on a clean, soft brush, and all holes, hole jewels, and cap jewels are pegged. Any tarnished pinion teeth should also be pegged. Use the brush sparingly, as excessive brushing will put grit and dirt back into the jewels and bearing holes. Pivots and pinions are pressed into soft pitch blocks to continue the cleaning process. During the drying process the air blower should be used constantly. With all parts, new and old, thoroughly cleaned, inspect the pivots, pinions, and wheels. Check to see that the pivots are polished, straight, and clean, and that the

teeth pinions and wheels are clean and not damaged. Check the jewels for tightness, cracked or chipped holes, and cleanliness. Be absolutely sure that every part is scrupulously clean. Be careful not to let the fingers touch any of the cleaned parts as rust, which can result in a short time, will spoil the finish. After drying, the movement is ready for oiling and reassembly. (For reassembly of the watch, see chapter 5.)

## PRECAUTIONS

After cleaning, the following precautions must be observed:

1. Handle the parts with tweezers only.
2. Be sure that the cleaning solution has fully evaporated from every part.
3. Inspect all parts for particles of pith or pegwood before reassembly.
4. Use the mainspring winder (*not* the fingers) to insert the mainspring into the barrel.

Watch cases are cleaned with a stiff brush and cleaning solution.

Since the same cleaning procedures are followed for Navy clocks as for watches, except that the pillar plates are too large to fit into the watch cleaning machine, those parts are cleaned separately by hand with a brush and jeweler's rouge.

## OILING

All kinds of machinery must be oiled to reduce the friction of the rubbing parts. Oiling saves power, preserves the surfaces, and makes for smoother operation. But, although factory machines are oiled after each 8 or 10 hours of use and an automobile is greased and oiled every 1,000 miles, the average timepiece, whose balance beats 18,000 times per hour, is oiled every 9 to 15 months. The importance of proper oiling of watches, when they do receive this service, cannot be emphasized too greatly.

There are three main classes of oils: mineral oils, animal oils, and vegetable oils. Mineral oils have the advantage of keeping fresh for a long time, but they do not stay where they are placed; that is, they spread. Animal and vegetable oils

stay in the desired position, but they dry rather rapidly and become thick and gummy. In practice, these oils are mixed together commercially in varying proportions, to produce a fairly satisfactory product for lubricating watches. Since 1943 a synthetic lubricant called M-56 b, which is well suited for watches, has been developed. Many watch repairmen now use this new oil. A thicker oil, known as clock oil, is employed to oil watch mainsprings, center arbors, stem winding and setting mechanisms, and clock parts. Keep the oil in small glass or agate oil cups. The oil should be changed at least twice a week and the cups cleaned before they are refilled. Always use the correct type of oil, making sure it is fresh and clean before using it.

## OILERS

Several types of oilers are commercially available, the most common being a very fine wire flattened on one end and fixed in a wooden handle. The size of wire used is determined by the amount of oil needed. Keep a set of different sized oilers for different types of watches. The paddle end of a new oiler should be given a few lengthwise strokes with a fine pivot file; the grooves then formed will allow the oil to flow more easily. Drilling a 1/10-mm. diameter hole through the paddle ends will aid in transferring the oil to a jewel hole or pivot efficiently. Oilers should always be pushed into pith (wood) before and after use to dry and clean them. Figure 48 shows several sizes of oilers with tubular protective covers, and a popular type of agate oil cup with its cover. A new supply of fresh oil should be taken from the oil bottle daily and transferred to the oil cup. This prevents dust and dirt from accumulating in the bottle. The oil cup should always be kept covered when not in use to exclude dust or foreign matter.

Great care should be taken when oiling watches and clocks, since oiling materially lengthens their life and increases their accuracy. Never rush the oiling job or slight it in any way. *Too much oil*, however, is just as bad as *too little oil*. An excess of oil on watch parts usually overflows onto the balance staff, hairspring, or other sensitive parts, causing parts to run slowly

and unevenly, and eventually to stop. The oiling process calls for just as much care as the cleaning operation. An under-

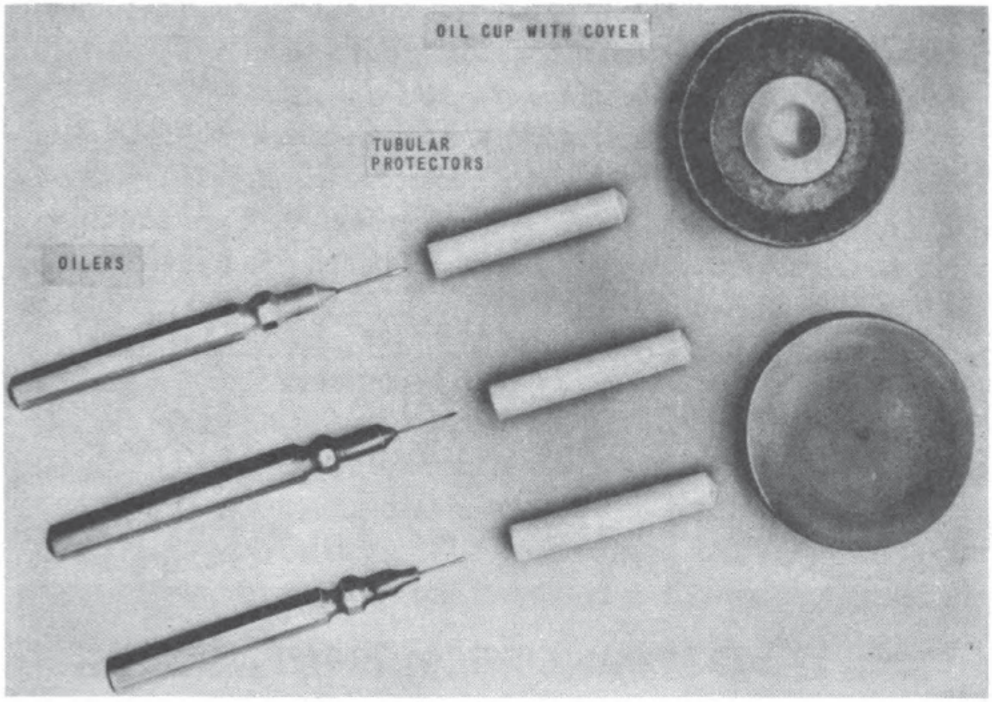



Figure 48. — Oilers and oil cup.

standing of the technique of oiling the different parts of a watch is essential for every Instrumentman.

## PARTS TO LUBRICATE

Generally speaking, the following parts of a watch should be lubricated:

1. *The mainspring, barrel arbor, and winding parts.* — Oiling must be done during assembly, since it is not possible to reach these parts after assembly. Two or three drops of clock oil are placed on the edges of the mainspring, and one drop on its inner coil. More than that may result in oil being forced out of the barrel when the mainspring is wound tightly. A small amount of oil should be applied to the shoulders of the barrel arbor before it is inserted in the barrel, and also to the detent that slides in the clutch lever. All the bearing surfaces in the winding and setting mechanism should be oiled, including the square of the winding arbor where it runs through the clutch wheel.

2. *Upper and lower bearings of the center staff.* — The lower

bearing should be oiled before the cannon pinion is placed on the center staff. In oiling these bearings, the oiler should touch the pivot and the bottom of the oil cup at the same time to prevent any lubricant from spreading onto the jewel's surface.

3. *Upper and lower bearings of the third wheel.*

4. *Upper and lower bearings of the fourth wheel.*

5. *Upper and lower bearings of the escape wheel.*

6. *Upper and lower bearings of the pallet.* — Care should be taken to see that the upper pallet staff bearing is not overoiled, because the oil would then run down in the narrow space between the pallet bridge and pallet and retard the staff's movement.

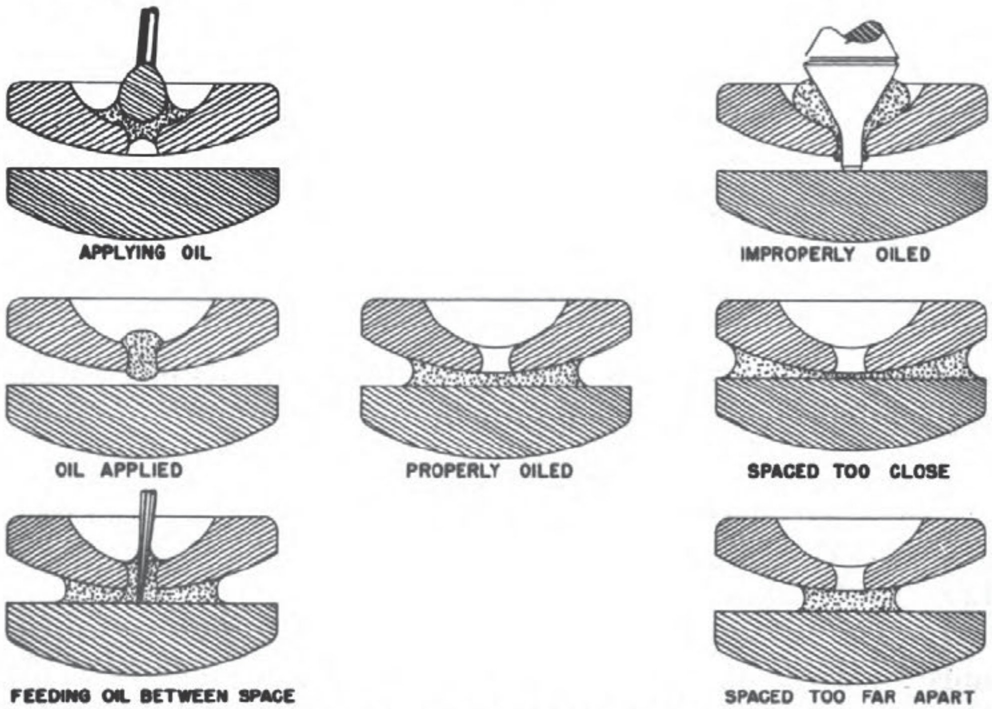



Figure 49.—Balance jewel properly and improperly oiled.

7. *Between escapement teeth and pallet jewels.* — An approved method of oiling the pallet stones is to apply the oil to three feet (every fifth one) of the escape wheel. As the escape wheel rotates, the oil will be distributed evenly upon all the feet of the wheel and onto the faces of the pallet stones.

An alternate method is to apply a small amount of oil to the locking face of the *R* (receiving) pallet stone (figure 13), moving

the fork lever backward and forward with a piece of pointed pegwood until the oil is transferred to the escape wheel teeth. With either of these methods, care should be taken to guard against overoiling. *Under no circumstances should the roller jewel be oiled.*

8. *Cap jewels.* — After the balance has been replaced in the movement, a small drop of oil is placed in the hole jewel oil cup with the oiler, and pushed down into the hole with a clean piece of fine polished wire. The position of the oil bubble between the jewels can be clearly seen with a loupe. If the bubble size appears to be too small, it may be increased by adding a small amount at a time. Capillary attraction holds the oil in its place and against the surfaces of the pivots. No oil should be allowed to touch the jewel setting as this would result in the oil being drawn away from the jewel hole, leaving the balance pivot dry. The correct and incorrect procedures for oiling balance jewels are indicated in figure 49.

## PARTS *NOT* TO LUBRICATE

It is not necessary to oil the following parts: (1) the dial train wheels, (2) the hairspring, (3) the teeth or pinions of the center, third, and fourth wheels, and (4) the roller jewel. The wheels need no oil because they move slowly and create little friction. Oil on the hairspring is extremely undesirable, since it causes the coils to stick together; this would have the effect of reducing the length of the spring, and the watch would run at a faster rate.

## STOWAGE OF TIMEPIECES

Common sense should always be exercised in stowing watches and clocks aboard ship. When the Supply Officer or the Repair Officer requests the Watch Shop to care for the ship's stock of timepieces, these instruments should be stowed in a place where they will be protected from dampness or extreme heat or cold. They should be kept in their original cartons to give them the protection of the specially designed cardboard liners.

You should always keep a few watches and clocks hanging up on the bulkhead, so that their rate may be established by

several weeks of operation before they are issued for service.

## SUMMARY

This chapter has explained the machine and hand methods of cleaning watches, the different cleaning solutions, and the processes used. It has also described the successive steps in oiling pocket watches, with the precautions to be observed as the parts are reassembled after cleaning.

From the above, it is evident that the cleaning and oiling process is just as important to the running of the watch as any of the intricate repair jobs that you will ever have to do. The hour or so spent on this operation is amply repaid by the greatly increased efficiency of the timepiece. In the Navy, an accurate, trouble-free watch is an absolute necessity.

## QUIZ

1. Which two methods of cleaning watches are in common use today, and which method is used in the Navy?
2. What are the main advantages of the machine cleaning method?
3. What four precautions should always be taken when cleaning watches?
4. How often should a watch be cleaned and oiled?
5. What are the three main classes of oils?
6. What are the properties of mineral oils when considered as watch and clock lubricants?
7. What are the properties of animal and vegetable oils when considered as watch and clock lubricants?
8. What kind of oil is generally used today for lubricating watches?
9. Which parts of a watch should never be oiled?
10. Where should watches and clocks be stowed aboard ship?

## CHAPTER 5

# WATCH CASUALTY ANALYSIS

## MODERN WATCHES

In chapter 3 you learned about the tools used in watch and clock repairing. The next thing is to start using them. The steps that you will follow in inspecting, cleaning, and repairing a watch are described in detail. In this chapter, you are given many practical suggestions to increase your knowledge of watch repair.

Watches of different makes vary slightly in their construction and in the position of the parts. Your sister's watch, for instance, is probably a very thin wrist watch with an attractive curved dial, while the watch your dad carries is of the thicker, heavier pocket type. But the basic principles of operation are the same in all watches.

## THE HAMILTON COMPARING WATCH

We will take the Hamilton comparing watch for an example. It is used to convey chronometer time to the clocks at ships' stations at intervals during the day. The Hamilton No. 2974 B, 16-size stem-wind, stem-set, open-face, 17-jewel, precision watch shown in figure 50 is generally used for this purpose.

It differs from the conventional 16-size watch by having a second-setting device which allows the second hand to be stopped at any predetermined second. The second hand stops when the stem is pulled out; the hour and minute hands can then be set for any time indication on the dial. When the stem is pushed in, the watch starts to run again. In this way the watch may be set in exact agreement with a ship's chronometer reading whenever such a setting is desired. Since the Hamilton comparing watch is repaired on Navy repair ships and at shore stations, we are taking that timepiece for our example.

## REPAIRING PROCEDURES

The standard watch cleaning and repairing procedure can be broken down into six basic operations:

1. Inspection before disassembly.
2. Disassembly.
3. Inspection after disassembly.
4. Cleaning.
5. Repair.
6. Reassembly (with oiling).

Each of these operations will be described separately in the order listed. When you come to perform them in a shop, remember that the watch is a very delicate piece of precision mechanism and should always be handled with extreme care. Always lift and move a watch slowly: lay it down gently. Use the correct tools for each repair operation. And finally, be careful not to touch any of the watch parts with your fingers after disassembly and cleaning, as this will cause the watch parts to rust after being in service a few weeks.

## FINDING OUT WHAT'S WRONG

Your job is to find out what is wrong with the watches and clocks that come to the shop, and to put them back into good working order. In military terms, this job is making the watch casualty analysis. The following table lists the common watch troubles, along with their causes and remedies. It covers practically every watch problem that you will meet. *Spend plenty of time studying this table, and use it constantly later on as a reference.*

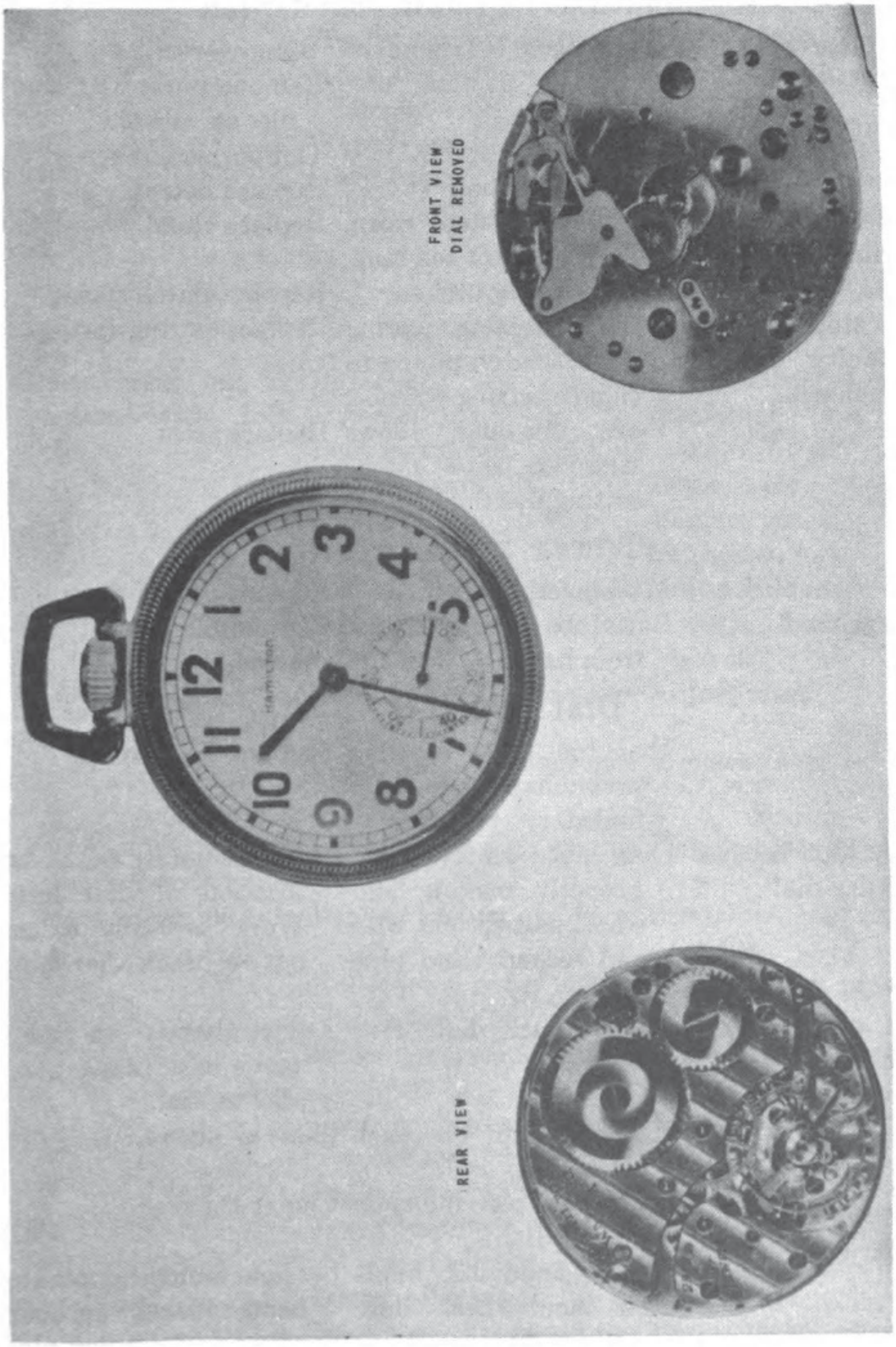



Figure 50.—The Hamilton comparing watch, No. 2974 B.

# WATCH TROUBLE ANALYSIS

| *Symptoms* | *Causes* | *Remedies* |
|---|---|---|
| | **WINDING AND SETTING MECHANISM** | |
| Crown unscrews. | Stem rusted into pendant. | Remove rust. |
| | Threaded portion of stem burred. | Remove burrs with fine file or oilstone. |
| Stem pulls out of case. | Loose detent screw. | Tighten detent screw. |
| | Damaged detent. | Replace detent. |
| Stem will not stay in winding position. | Shoulder on stem worn. | Replace stem. |
| | Square on stem too long. | |
| | Clutch spring broken. | Replace clutch spring. |
| Watch stops because of faulty winding mechanism. | Broken setting spring allows clutch pinion to engage setting wheel. | Replace setting spring. |
| | Worn shoulder allows stem to shift into setting position. | Replace stem. |
| | **POWER MECHANISM** | |
| Watch cannot be fully wound. | Mainspring broken. | Replace mainspring. |
| | Barrel cover disengaged from barrel. | Reassemble barrel assembly. |
| | **DIAL AND HANDS** | |
| | Dial too loose, causing second hand to become fouled. | Tighten dial screws. |
| Watch stops because of faulty dial. | Dial not centered properly, making hour wheel and second wheel and second hand pipe bind on it. | Position dial by changing location of dial feet. Work carefully so as not to break dial feet. |
| Watch stops because of improperly positioned hands. | Hands touch dial or crystal. | Adjust hands so they move in a plane parallel to dial. |
| | Hands catch on each other. | Same as above. |
| | Hour hand pipe binds on hole in dial. | Center the dial. |
| | Minute hand hub binds on hour-wheel hub. | Set hour hand and minute hand squarely on hour wheel and cannon pin, respectively. |

| *Symptoms* | *Causes* | *Remedies* |
|---|---|---|
| Hands fail to indicate correct time. | Hands loose on either hour wheel or cannon pinion.<br>Hands not properly set.<br>Hour and minute wheels become enmeshed.<br>Watch runs, but hands do not move. | Tighten hands so that when watch is set for 12 o'clock, both hour and minute hands are pointed at figure 12 on the dial.<br>Place dial washers on hour-wheel pipe between hour wheel and dial.<br>Tighten cannon pinion. |
| | ESCAPEMENT | |
| Roller jewel out of action with fork slot. | Improperly set pallet jewels. | Reset pallet jewels. |
| | Bent guard pin. | Straighten and adjust pin. |
| | Broken guard pin. | Replace pin. |
| | Guard pin too short. | Replace pin. |
| | Bent fork. | Straighten fork. |
| | Too much sideshake or endshake in pallet or balance. | Adjust bridges or replace staffs, bushings, or jewels. |
| | Banking pins improperly adjusted. | Adjust pins. |
| | Roller table of improper size. | Replace roller table. |
| Watch stops because of faulty escapement assembly. | Escapement dirty or improperly oiled. | Disassemble, clean, and re-oil. |
| | Bent or broken pivots. | Straighten or replace pivots. |
| | Roller jewel out of action with fork slot. | See symptom previously mentioned. |
| | Burrs on escape wheel. | Remove burrs with fine file or oilstone. |
| | Bent or broken escape-wheel teeth. | Replace wheel. |
| | Broken jewels. | Replace jewels. |
| | Jewel improperly set or loose in setting. | Reset jewel. |
| | Loose roller jewel. | Reset jewel. |
| | Excessive oil on upper pallet staff pivot. | Disassemble, clean, and lubricate. |

| *Symptoms* | *Causes* | *Remedies* |
|---|---|---|
| | **BALANCE ASSEMBLY** | |
| Watch stops because of faulty balance assembly. | Bent or broken balance staff. | Replace staff. |
| | Broken or loose balance jewels. | Replace jewels. |
| | Dirty balance or balance jewels. | Disassemble, clean, and lubricate. |
| | Broken or loose roller jewel. | Replace or reset jewel. |
| | Loose roller table. | Replace or tighten roller table. |
| | Bent hairspring. | Straighten or replace. |
| | Broken hairspring. | Replace hairspring. |
| | Oil on hairspring. | Clean balance. |
| | Magnetized hairspring. | Demagnetize watch. |
| | Loose balance screws. | Tighten screws. |
| | Balance untrue. | True balance. |
| | Balance loose on staff. | Stake balance on staff. |
| | Loose balance bridge. | Tighten balance cock screw. |
| | Excessive endshake or sideshake. | Adjust. |
| | Balance rim strikes center wheel, hairspring stud, regulator pins, or some other point. | Check balance jewels for correct position and depth, center wheel for trueness, hairspring stud for correct position, and balance cock for burrs on underside. |
| | Balance rim strikes pallet bridge. | Check lower balance jewels for proper depth; check underside of pallet bridge for burrs; see that pallet bridge is properly screwed into position. |
| | Smaller roller table strikes lower hole jewel setting shoulder. | Turn shoulder back or replace jewel. |
| | Edge of safety (small) roller is rusted or gummy. | Buff and polish edge of roller with hand buff. |

| *Symptoms* | *Causes* | *Remedies* |
|---|---|---|
| Watch runs too fast because of faulty balance assembly. | Oil on hairspring. | Clean hairspring. |
| | Magnetized hairspring. | Demagnetize. |
| | Other than outside coil of hairspring between regulator pins. | Release spring. |
| | Twisted or bent hairspring. | Straighten or replace. |
| | Balance not properly poised. | Poise balance. |
| | Regulator pins bind hairspring. | Spread regulator pins. |
| | Improper hairspring. | Replace spring. |
| | Balance screws missing. | Replace screws. |
| | Hairspring strikes center wheel or some other point. | Adjust spring so it will not touch adjacent parts. |
| | Hairspring and balance dirty or gummed with oil. | Clean balance. |
| | Regulator pins spread too far apart. | Close pins. |
| | Balance rim strikes other part of watch. | Check position of balance as related to balance cock, pallet bridge, center wheel, regulator pins, or hairspring stud. (Make test with watch setting in different positions.) |
| Watch runs too slow because of faulty balance assembly. | Bent balance staff. | Replace staff. |
| | Broken balance jewel. | Replace balance jewel and balance staff if it has been bent or cut by broken jewel. |
| | TRAIN MECHANISM | |
| Watch stops because of faulty train mechanism. | Teeth or pinions of train wheels dirty. | Disassemble and clean. |
| | Movement improperly oiled or oil gummy. | Disassemble and clean. |
| | Teeth or wheels bent. | Straighten teeth or wheels and replace wheels if necessary. |

| Symptoms | Causes | Remedies |
|---|---|---|
| | Burrs on teeth of wheels. | Remove burrs. |
| | Bushings worn. | Replace bushings. |
| | Improper depthing of wheels and pinions. | Replace or rebush wheels. |
| | Not sufficient sideshake or endshake for wheels. | Straighten plates or burnish pivot holes. |
| | Bent pivots. | Straighten pivot or replace wheels. |
| | Cracked plate jewel. | Replace jewel. |
| | Jewels improperly set. | Reset jewel. |
| | Loose jewel in setting. | Reset jewel. |
| | Loose bridge plate. | Tighten screws. |

## INSPECTION BEFORE DISASSEMBLY

If the watch is not running properly when you receive it, determine the cause of failure *before disassembly*, if possible. To do this expertly, experience is necessary. A thorough inspection should always be made before disassembly, since it may be difficult or even impossible to locate a defect after the watch has been disassembled. In this discussion we will again take the Hamilton comparing watch, No. 2974 B, as our example. The initial inspection should be made as described below.

*The watch case.* — First inspect the watch case carefully for completeness, looking for dents in the case and a scratched or loosened crystal. Check the case to see if it is sprung, or if it has a worn or loose crown or bow. Make sure that the case threads are not dented or broken. Check the adjustment of the stem to be sure that the winding and setting mechanism operates smoothly.

*The winding and setting mechanism.* — Try out this mechanism for smoothness of operation. The stem is sometimes so loose that it will come right out of the movement when you start turning it. If the watch cannot be fully wound, it indicates the possibility of a broken mainspring. See whether the winding wheels seem to slip when the watch is being wound. Notice whether the hands can be set. Check the tightness of the cannon pinion on the center arbor.

*The dial.* — Inspect the dial for general appearance and for the legibility of its figures. Also inspect for trueness of the dial feet, to be sure that the dial is perfectly centered and that the pinions carrying the hands are not binding.

*The hands.* — Observe whether the hands are properly adjusted. Make sure they do not rub on the dial or crystal, or catch on one another when moved. (If the hands are not properly adjusted, check their position in relation to the numerals on the dial. Both the minute and hour hands should be pointing to the figure 12 on the dial when the watch is set at 12 o'clock.)

*The balance assembly.* — By the simple method of listening to the watch's balance in different positions, a broken pivot can be detected. Look to see if the balance staff is broken, and whether the balance wheel is true. If the watch is clean and the oil is not gummy, and all the working parts seem to be in good order but the balance motion appears to be erratic, check the movement for magnetism or for a fouled, oil-laden hairspring. (The cause of magnetism in watches and its remedy is given in chapter 6.) Observe the action of the fork and the roller for any irregularity there.

*The train wheels.* — Finally, inspect the train wheels closely to see if they move freely and mesh properly.

## DISASSEMBLY

Under ordinary conditions a Navy comparing watch, in service, should be disassembled and cleaned at least once every 12 months, depending on the use and care it has received. It is highly desirable that disassembly of this watch be accomplished in the order shown below.

*Remove the bezel and hands.* — Holding the watch in the right hand, unscrew the bezel (crystal holder) from the case. Remove the minute hand, the hour hand, and the second hand, using the plunger-type hand remover (see figure 51). (It is good practice to protect the dial face with a piece of paper or used photographic film having a V-shaped opening cut to fit.) Check the fit of the hands to their respective bearings, then lay the hands aside in a small container for safekeeping. Now turn the

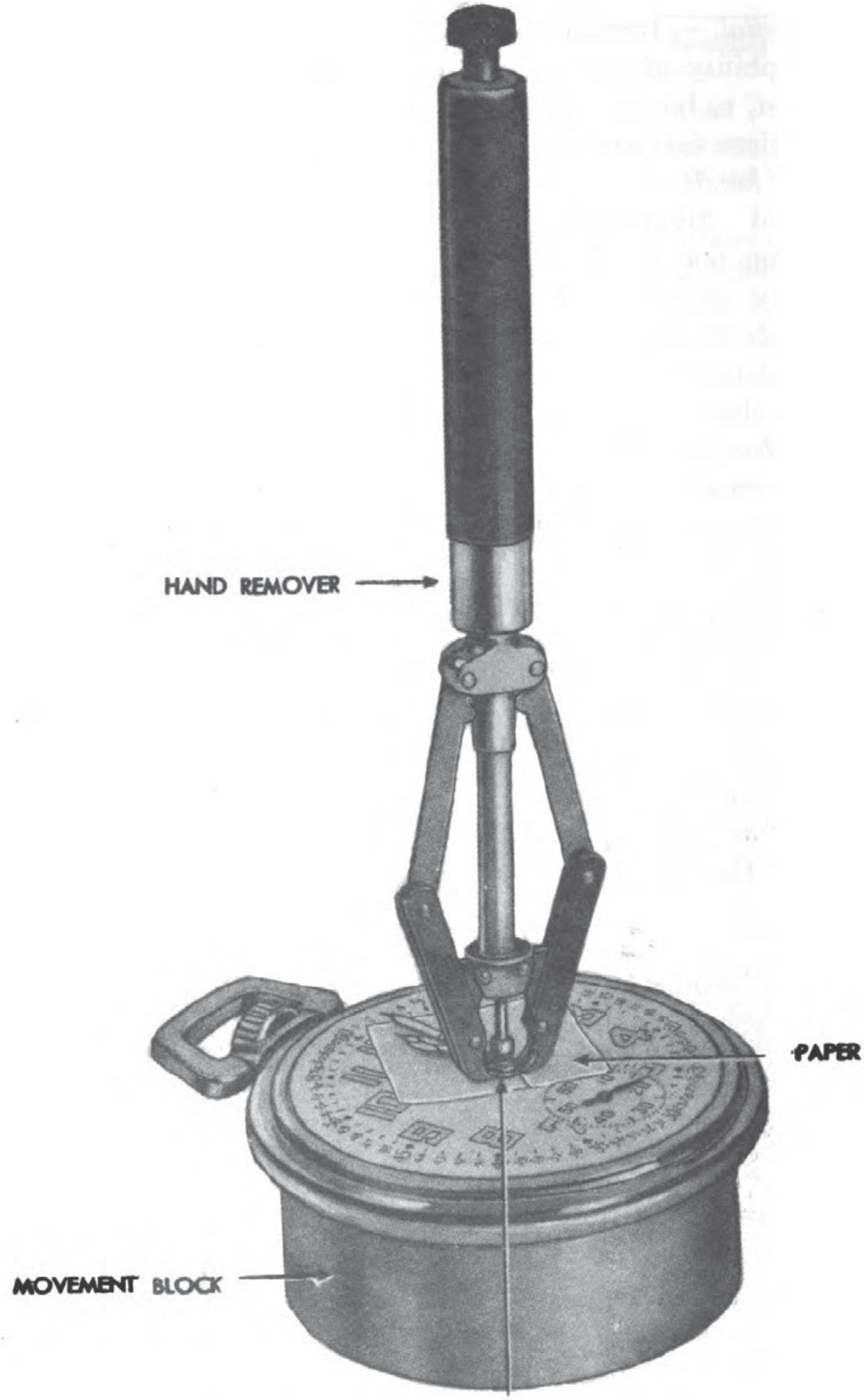


Figure 51.— Removing hands with hand remover (plunger type).

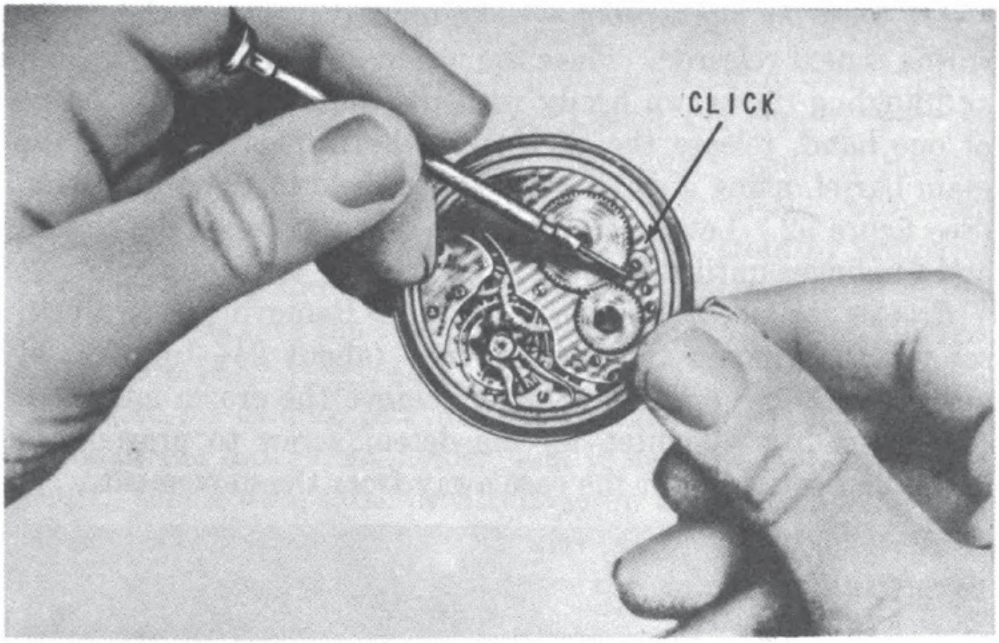



Figure 52. — Releasing the power of the mainspring.

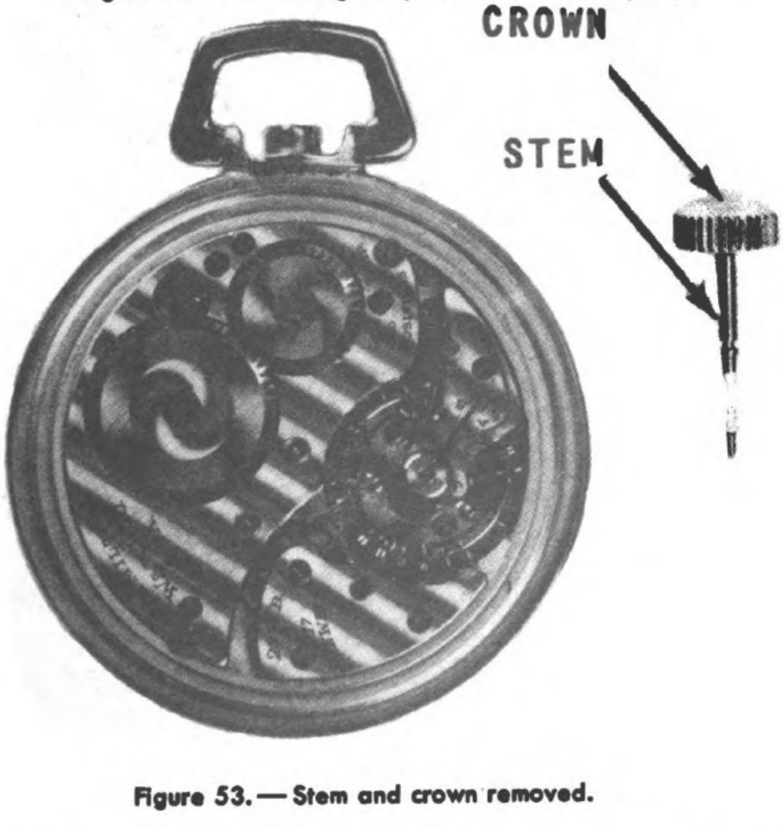



Figure 53. — Stem and crown removed.

watch over, unscrew the back of the case, and gently pry off the case dome with a case knife.

*Let down the mainspring.* — The unused power in the mainspring is next released. Place the watch on a movement holder, and holding the crown firmly with the thumb and index finger of one hand, release the click from the ratchet wheel on the main barrel, using a small pointed tool held in the other hand. (See figure 52.) Let the crown rotate slowly between the thumb and forefinger until the power is completely let down.

*Remove the movement from the case.* — Remove the two case screws, then loosen the detent screw (about 2½ turns), and using the thumb and index finger remove the crown and stem (see figure 53). Tighten up the detent screw to prevent its loss. You can then lift the case away from the movement.

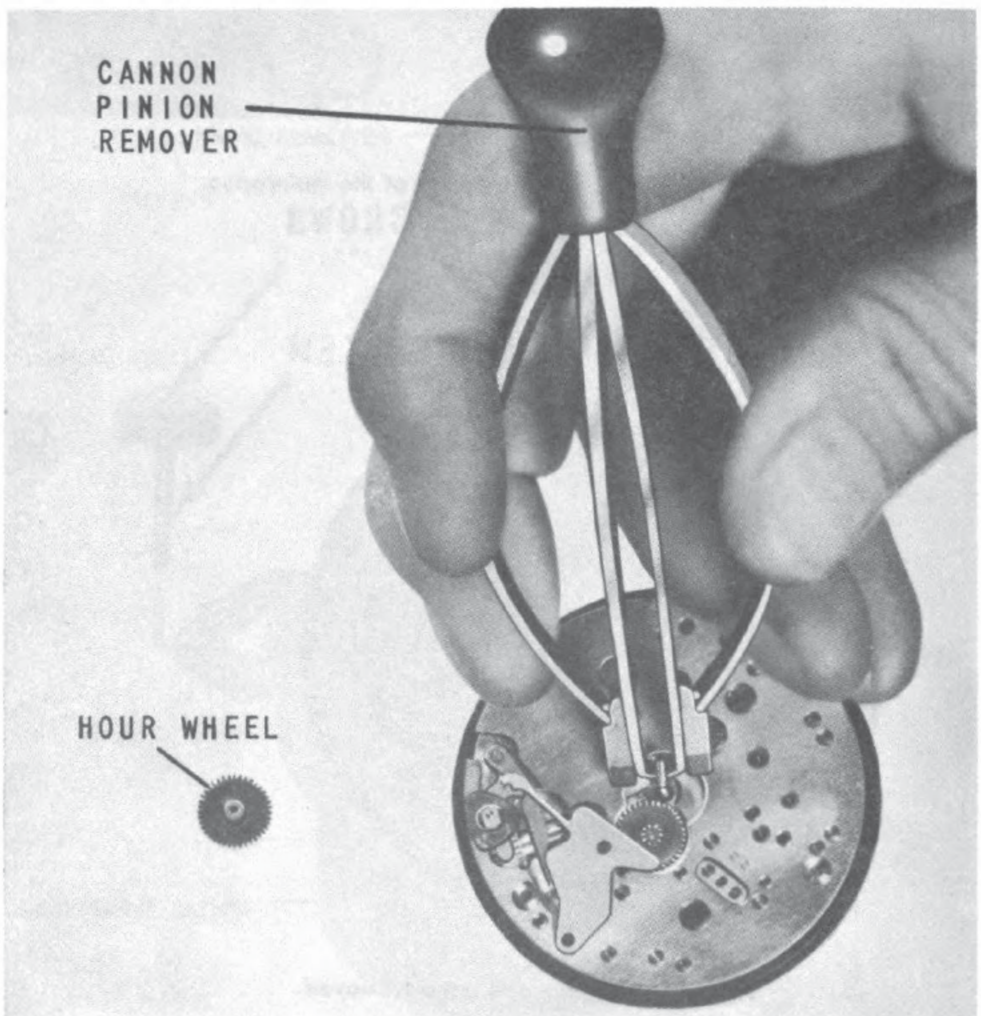



Figure 54. — Removing the cannon pinion. Hour wheel removed.

*Remove the dial and the dial train.* — Loosen the three dial foot screws on the edge of the pillar plate, and with a screw driver lift the dial off the plate. Check the condition of the dial feet. Set the dial feet screws in snugly again to prevent their loss. Next, turn the movement over in the movement holder, and start the disassembly of the dial train by removing the hour wheel and the cannon pinion. Use a cannon pinion remover to remove the cannon pinion, lifting it straight upward. (See figure 54.)

*Remove the balance cock assembly.* — Reverse the movement again in the movement holder, and loosen the hairspring stud screw; then with a small broach or screw driver loosen the stud. Remove the balance cock screw and take off the balance cock assembly. (See figure 55.) Secure the hairspring stud screw

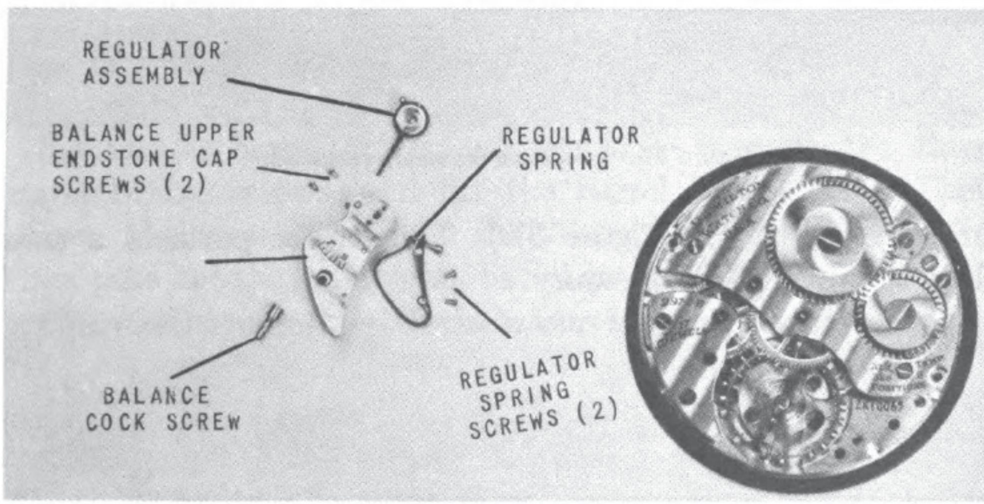



Figure 55. — Balance cock removed and disassembled.

in place to guard against its loss. If the balance cock is tight, insert a screw driver in the slot beneath it and gently pry it loose. Set the balance cock assembly upside down on a piece of pithwood, and remove the two endstone cap screws. Turn over the balance cock and remove the two regulator spring screws. You can then lift off the regulator spring and regulator assembly.

*Remove the balance wheel assembly.* — Lift the balance assembly free of the movement, using tweezers, and lay it aside in a safe place. (See figure 56.)

*Remove the pallet bridge and fork assembly.* — Remove the two pallet fork bridge screws; then take off the pallet bridge and

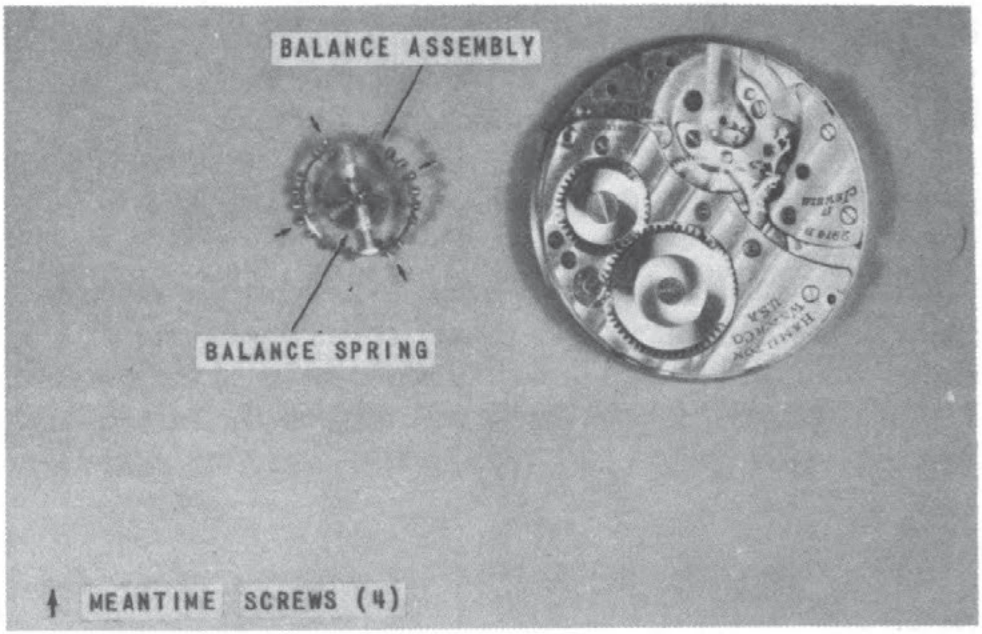



**Figure 56. — Balance assembly removed.**

fork assembly. (See figure 57.) Place these parts in a safe place to prevent loss or injury.

*Remove the winding and ratchet wheels.* — Remove the winding

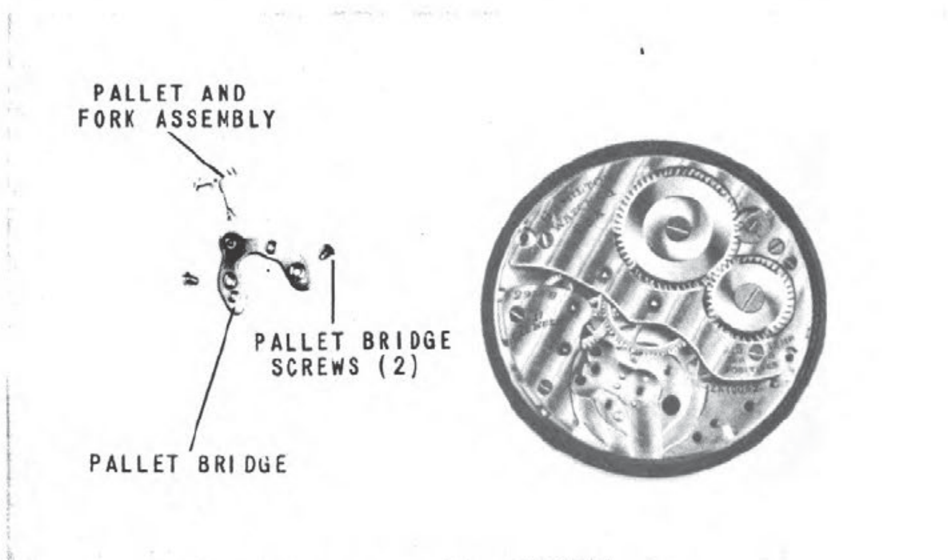



**Figure 57. — Pallet bridge and fork assembly removed.**

wheel screw and the winding wheel. Remove the ratchet wheel screw and the ratchet wheel. Then remove the click screw, the click, and the click spring. (See figure 58.)

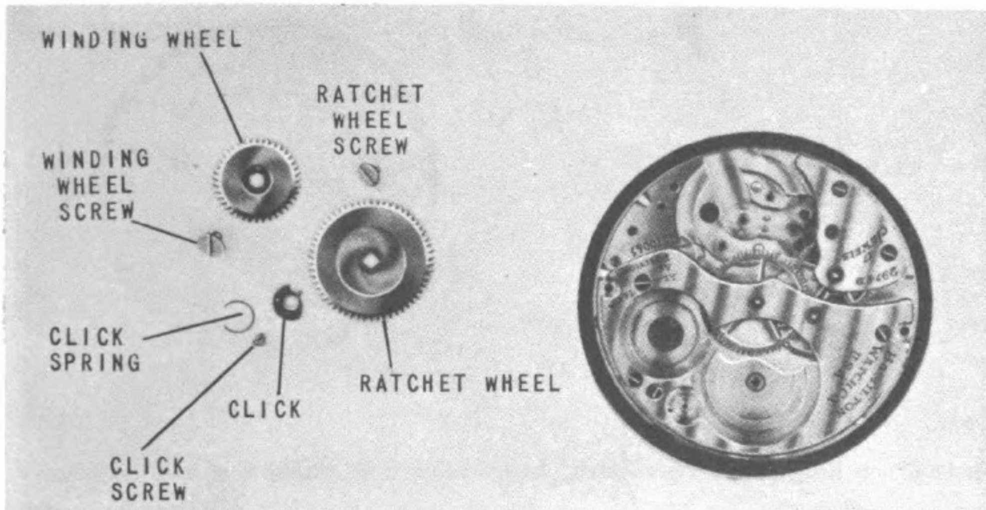



Figure 58. — Winding and ratchet wheels removed.

*Remove the barrel bridge and wheels.* — Remove the three barrel bridge screws, and lift the barrel bridge free. Then remove the center wheel and the third wheel. (See figure 59.) Then take out the mainspring barrel assembly.

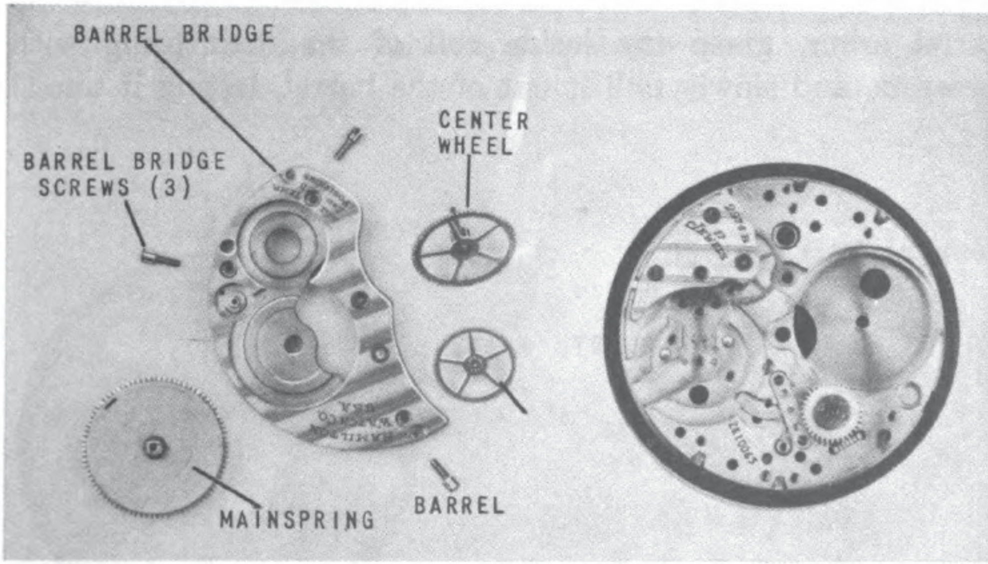



Figure 59. — Barrel bridge with barrel, center wheel and third wheel removed.

*Disassemble the mainspring barrel.* — Set the barrel assembly on a piece of pithwood and remove the barrel cap by inserting

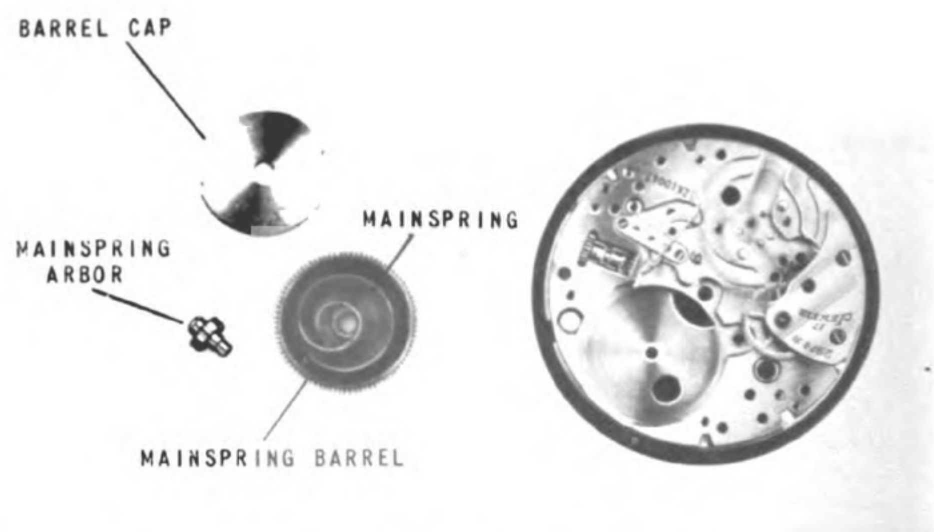



Figure 60.—Barrel with mainspring, barrel cap and mainspring arbor removed

a small screw driver in the slot provided for that purpose, and gently prying the cap loose. (See figure 60.) Then remove the barrel arbor and the mainspring. To remove the mainspring from the barrel, hold the mainspring barrel in your hand between the thumb and index finger, tap the arbor lightly with a small brass or rawhide hammer until the cap slides off. Remove the barrel arbor, grasp the inside coil of the mainspring with tweezers, and slowly pull it out of the barrel, letting it uncoil

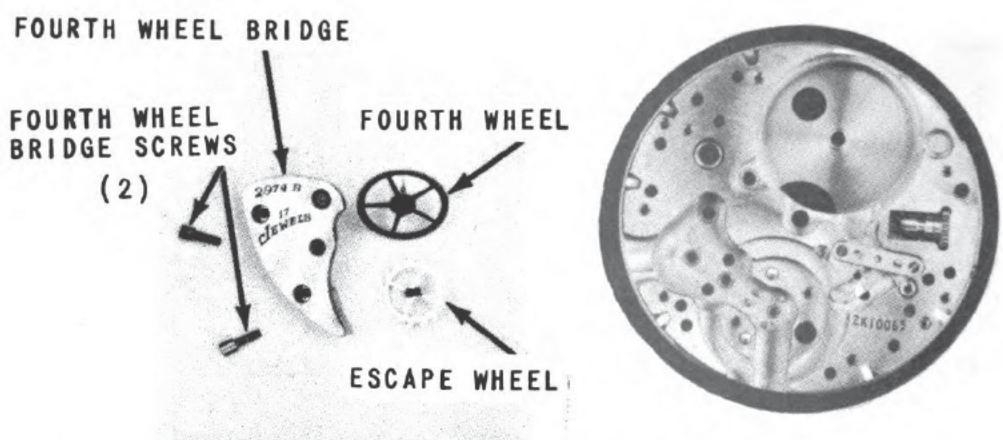



Figure 61.—Fourth wheel bridge, fourth wheel and escape wheel removed.

as it comes out. (Be careful not to touch the mainspring with your bare fingers; always use watchmaker's tissue.) Next remove the fourth wheel bridge screws, and lift the fourth wheel bridge free. You can then take out the fourth wheel and the escape wheel. (See figure 61.)

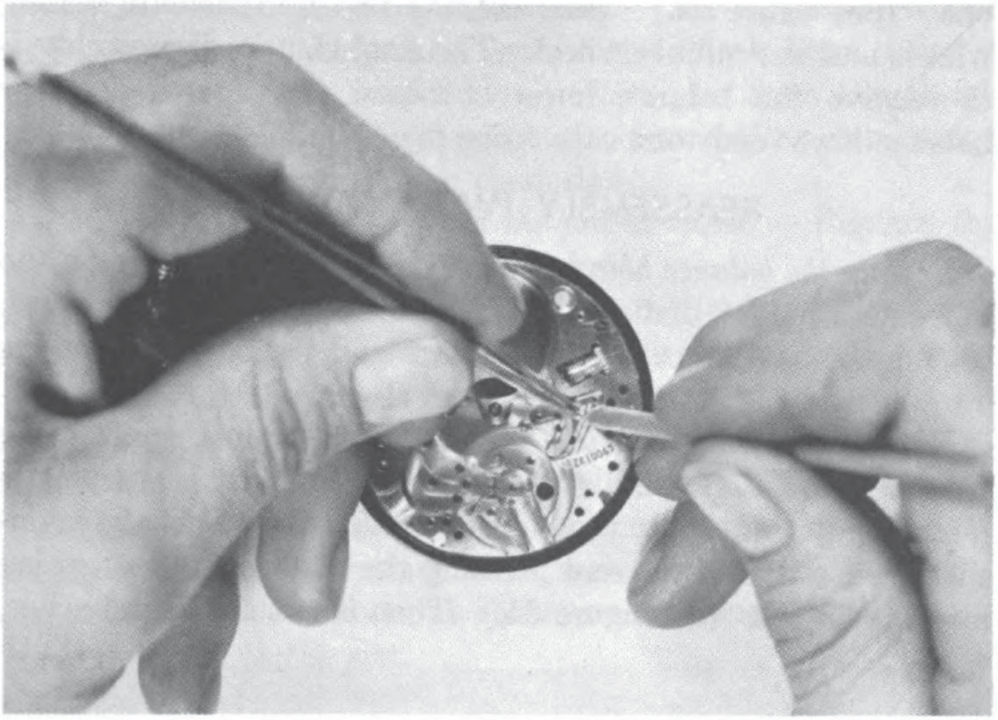


Figure 62.— Releasing the clutch lever spring.

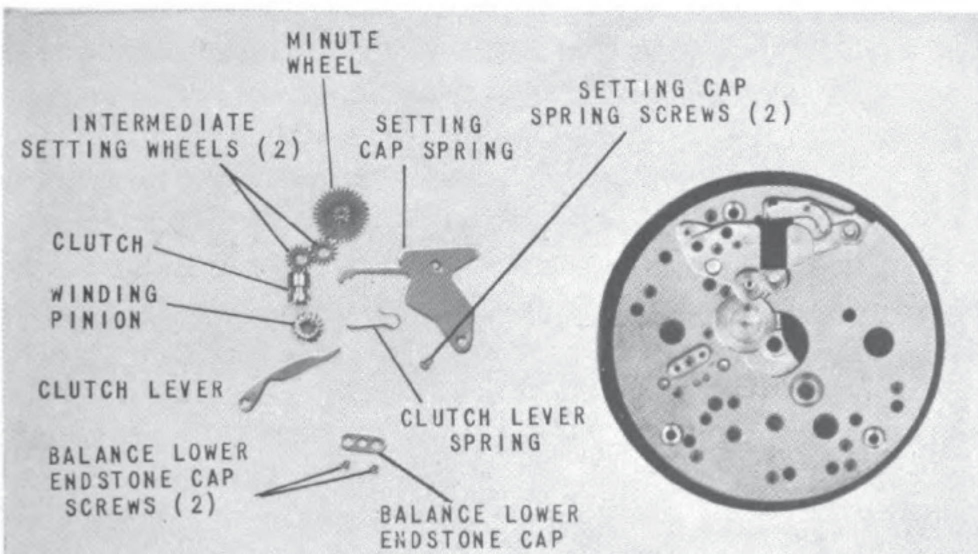



Figure 63.— Setting assembly and balance lower endstone cap removed.

*Remove the winding and setting mechanism.* — Remove the two setting cap spring screws, and the setting cap spring. Then remove the clutch lever and the clutch lever spring. When doing this, use a piece of pegwood cut with a 45 degree angle flat edge, to hold the spring in place and prevent it from snapping out. (See figure 62.) Take out the two intermediate setting wheels and the minute wheel. The final step in disassembly is to remove the balance lower endstone cap screws, and the balance lower endstone cap. (See figure 63.)

## REASSEMBLY (WITH OILING)

*Replace the balance hole jewel.* — Place the pillar plate on the movement holder, dial side up. Replace the balance hole jewel, setting the bottom cap jewel in place and tightening down the two balance cap jewel screws.

*Wind in the mainspring.* — Select the proper mainspring winder and slowly wind the mainspring into it, inserting the mainspring winder into the barrel, hooking the end of the mainspring onto the barrel, and pressing the end of the mainspring into the barrel. (See figure 64.) Then insert the barrel arbor,

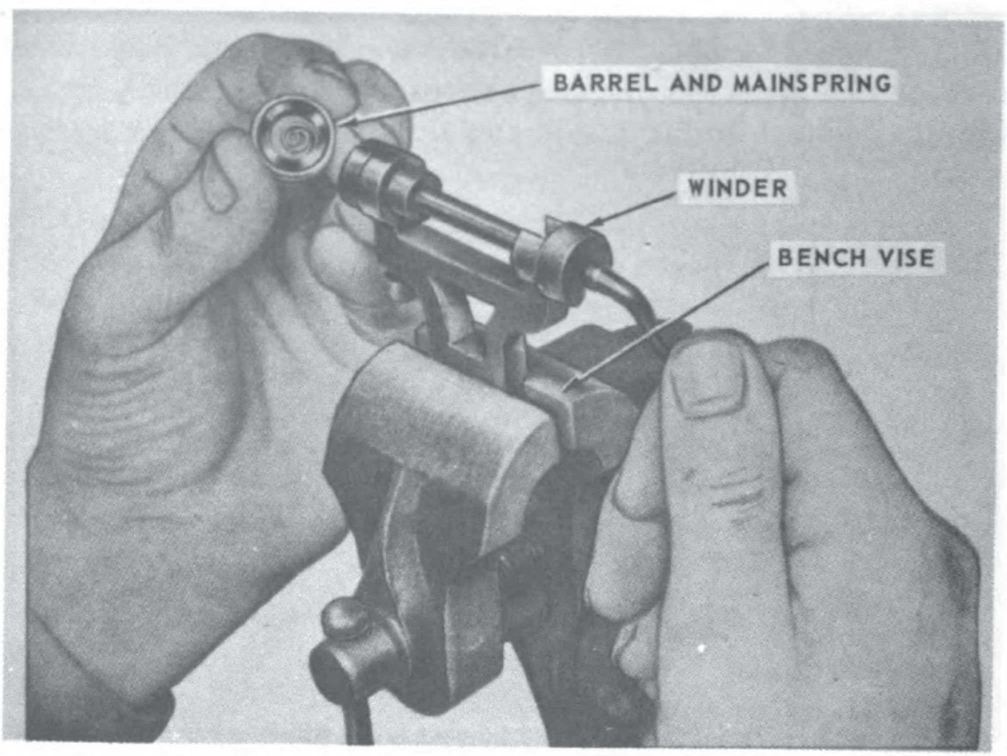



Figure 64. — Assembling mainspring into barrel, using mainspring winder.

oil the spring and replace the barrel cap, snapping it into its recess. To press the barrel cap into place, use two pieces of pegwood with ends cut at an angle. *Oil the mainspring with a good grade of clock oil before the barrel is replaced, by touching its edge with about five small drops of oil on an oiler.*

*Replace the seconds setting mechanism.* — Invert the movement in the movement holder and replace the clutch lever, using a piece of pegwood to hold it down while you push the clutch lever spring into its place. Put the two setting cap spring screws into place and tighten them down.

*Replace the escape wheel and the fourth wheel.* — Replace the escape wheel and then the fourth wheel.

*Replace the fourth wheel bridge.* — Set the fourth wheel bridge in place over the escape wheel and the fourth wheel. Use a fine broach to work the wheels into place while pressing down on the bridge with a piece of pegwood. Then tighten down the two fourth wheel bridge screws, and test the wheels for freedom.

*Replace the barrel assembly.* — Replace the mainspring barrel assembly in the pillar plate, then replace the third wheel and the center wheel. Next put the lower winding wheel into its place over the clutch slot.

*Replace the barrel bridge.* — Replace the barrel bridge, and gently work all the pivots into place. Press a piece of pegwood against the barrel's edge to see if all the wheels move freely. Secure the barrel bridge in place with the three barrel bridge screws. Then use the piece of pegwood again to test the wheels for freedom. *Lubricate the mainspring arbor pivot by placing a small drop of oil there.*

*Replace the setting mechanism.* — Replace the ratchet wheel and tighten down the ratchet wheel screw. Then invert the movement in the movement holder, bringing the dial side up again, and replace the winding wheel in its slot and the clutch wheel in its place. *Oil the staff of the stem*, and replace the stem in the movement, tightening the detent screw which holds the stem in place. Replace the clutch lever and the clutch lever spring. Use the pegwood to hold the spring while you work it down into its place. Replace the two intermediate setting wheels and the minute wheel. Then replace the setting cap

and tighten down the two setting cap screws. *Lubricate the end of the second setting cap spring with a small drop of oil.* Then invert the movement, and *place a small drop of oil between the lower winding wheel edge and the pillar plate.* Replace the upper winding wheel, and tighten down its screw.

*Replace the winding assembly.* — Replace the click spring, the click, and the click screw. *Oil the pivots of the center wheel, the third wheel, the fourth wheel, and the escape wheel.* At this point, an examination must be made to check the freedom of the train. Do this by winding the mainspring one full turn with the key winder; if the wheels of the train "backlash" upon reaching the end of the winding, the train has perfect freedom. If they stop abruptly or slow down and gradually stop, a bind exists and must be corrected. (This mechanism must be oiled before this check is made.)

*Replace the pallet and the pallet bridge.* — Replace the pallet fork in the pillar plate. Replace the pallet bridge, carefully alining the pallet arbor pivot in its hole, and tighten down the two screws of the pallet bridge. Check the pallet assembly for freedom. (The action of the pallet and escape wheel is checked by winding the mainspring two turns.)

*Replace the balance cock assembly.* — Place the upper cap jewel upside down and position the regulator on top of it. Line up the two cap jewel screw holes and, holding the balance cock in place with a piece of pithwood, replace one spring regulator screw and then the other. Invert the balance cock again, and *lubricate the upper and lower balance hole jewel.* Replace the balance assembly and tighten down the hairspring stud screw. Then lift the balance cock, with the balance wheel attached to it, and gently work it into place in the movement, placing the balance wheel under the center wheel and engaging the roller jewel pin in the slot of the pallet fork. Then tighten down the balance cock screw. With the watch running, *touch the pallet feet three or four times with a small oiler to lubricate the pallet stones and the escape wheel feet.* The escapement mechanism is now back in place and ready to function. (See figure 65.)

*Replace the cannon pinion and intermediate wheel.* — Loosen the three dial foot screws and invert the movement in the holder.

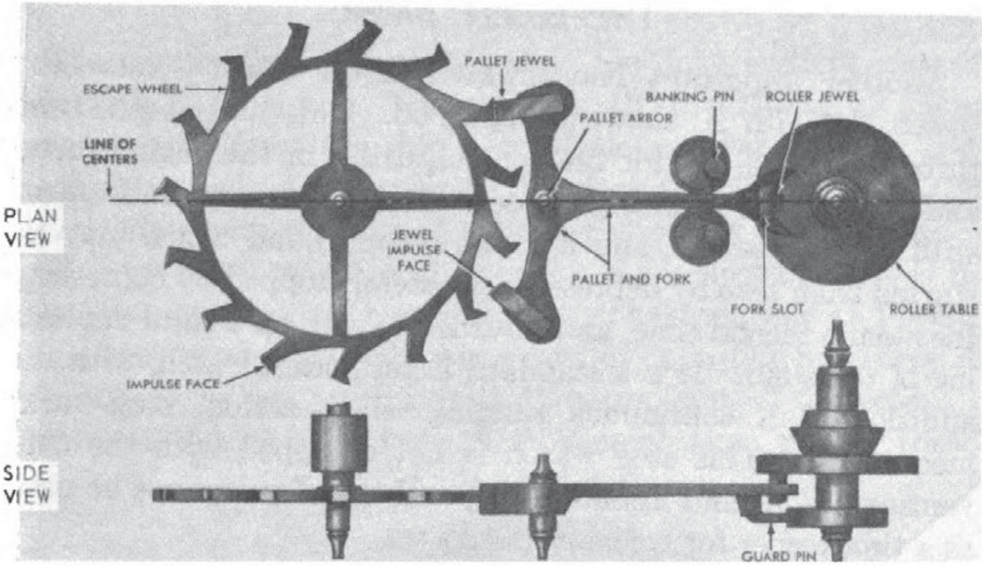



**Figure 65.— Relative positions of escape wheel, pallet and roller assembly parts.**

Position the cannon pinion on the center wheel, and press it into place, making sure that the cannon pinion has the same amount of friction all around. Replace the intermediate wheel, making sure that it meshes with the cannon pinion.

*Replace the hour wheel.* — Set the hour wheel in place on the cannon pinion, making sure that the hour wheel meshes properly with the pinion on the intermediate wheel.

*Replace the dial.* — Lay the dial in place, and tighten up on the three dial foot screws.

*Replace the hands.* — Set the hour hand in place, and press it down. Now replace the minute hand, making sure that both hands point to 12. Then replace the second hand.

*Replace the movement in the case.* — Loosen the detent screw and remove the stem and crown. (See the section on "Disassembly.") Lower the movement carefully into the case band, and tighten the two case screws. Then replace the stem and crown.

*Replace the case back.* — Replace the case dome, and screw the back of the case into place.

*Replace the bezel.* — Invert the movement and screw the bezel onto the front of the case. This completes the assembly of the Navy comparing watch.

## THE ELGIN TIMER

Another important Navy watch is the Elgin Timer stop watch No. 1787 A, shown in figure 66. This timepiece is used throughout the day for fire control, drills, in the engine room, and for general timing purposes. It has a 16-size movement with 7 or 15 jewels, and a sweep second hand which may be started from zero by depressing the stem, stopped by depressing the stem a second time, and returned to zero by a third depressing of the stem. It is a standard Elgin pocket watch, with the addition of a continuous running, single-action, stop-works mechanism. This stop watch is not equipped with the conventional hour and minute hand, and therefore cannot be used as a timekeeper for ordinary purposes.

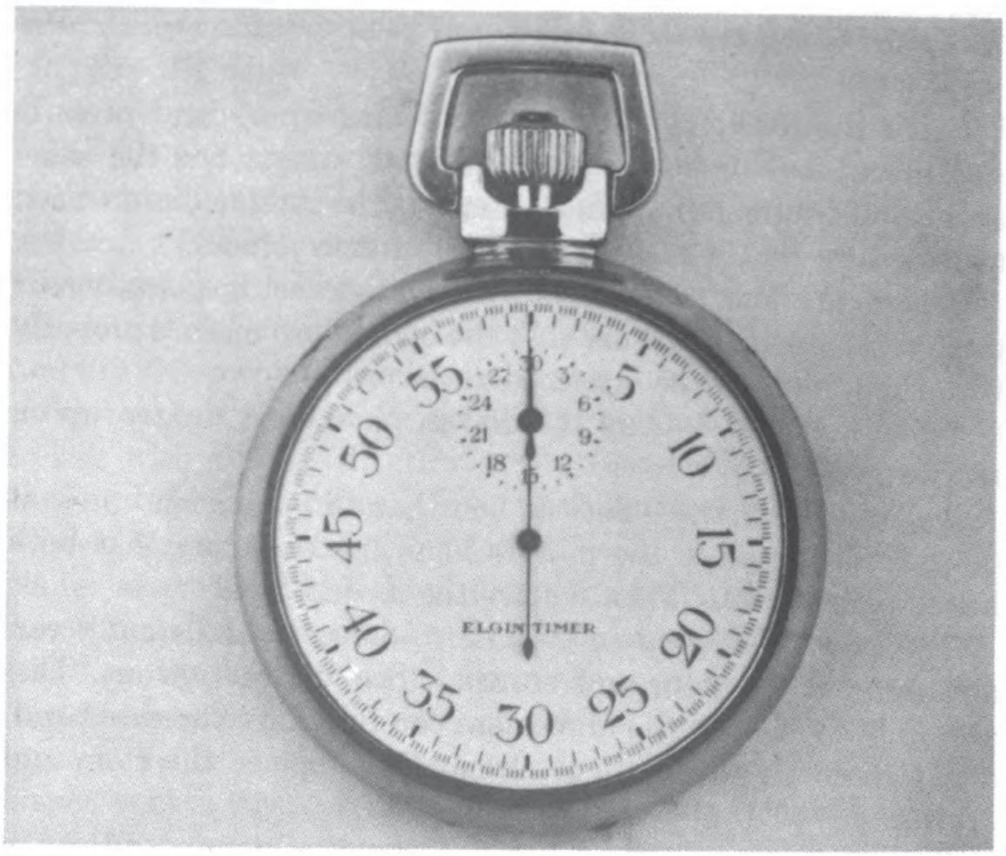



Figure 66. — The Elgin Timer stop watch, No. 1787 A.

Besides these two watches (the Hamilton comparing watch and the Elgin Timer), you may be called upon to service and repair various makes of waterproof wrist watches. You will also repair the different types of standard Navy clocks.

## NAVY CLOCKS

The correct time is maintained at the duty stations aboard ship with Navy clocks. Once a week, the quartermaster takes accurate time from the ship's chronometer on the bridge, and then visits each station, winds the clock, and resets it to the correct time with the help of a Navy comparing watch.

Modern Navy mechanical or engine room clocks are cased in plastic moisture-proof hinged cases. They contain 11 jewels. Their hour hands make either one revolution in 24 hours (type A movement), or one revolution in 12 hours (type *B* movement). Figure 67 illustrates a type *B* movement from one of these


**Figure 67.—Navy 6-inch mechanical clock, phenolic case (type *B* movement).**

clocks. Disassembly and reassembly of a Navy 6-inch deck clock is accomplished in the same general manner as for the Navy comparing watch. The cleaning process is also similar, but the larger clock movement and clock parts must be dipped into the cleaning solution by hand.

In general, the method of repairing Navy clocks is very

similar to Navy watch repairing; but the different construction of clocks calls for several minor departures in the repair procedure. The escapements of Navy clocks are designed as complete units. This makes them quickly replaceable, and greatly simplifies Navy clock repair. A view of the front of one of these clocks, with dial removed, is shown at the left in figure 68; a back view is shown at the right of that illustration.

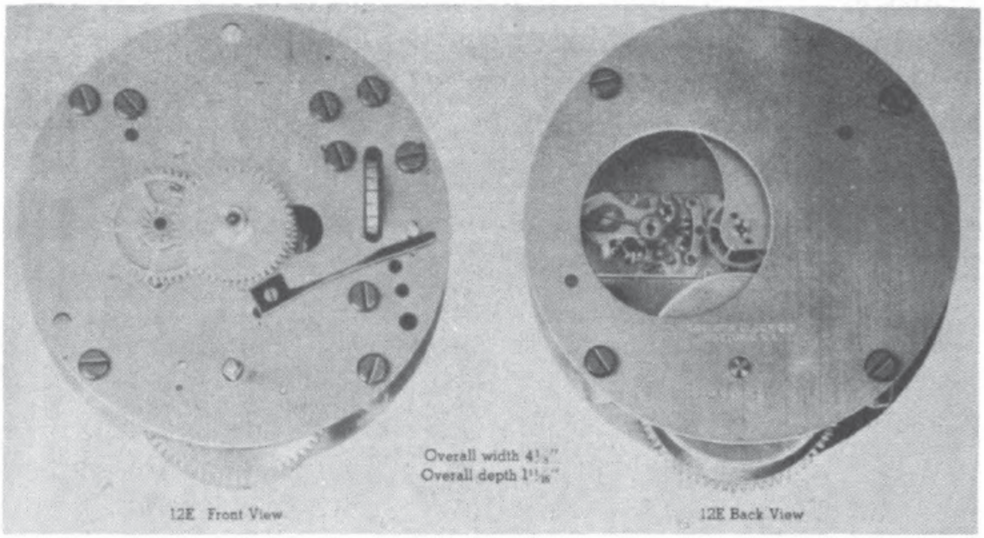



**Figure 68.—Views of a Navy 6-inch mechanical clock, with dial and back plate removed.**

The setting mechanisms of Navy clocks, like the escapements, are built in as separate units; they are operated with a hand key instead of by a stem-winding device. The hands on many of these clocks, being too heavy to depend on a friction fit, are held in place by a lock screw or a lock nut. Also, since most clock parts are too large to be moved about with tweezers, the repairman must move them by hand. Always use watchmaker's lint-free paper when handling clock parts.

Clock repair work requires a 6-inch screw driver, a pair of large tweezers, and a special mainspring key, in addition to the usual watch repair tools.

## NAVY CHRONOMETERS

The most accurate Navy timepieces are the chronometer and the chronometer watch. These timepieces are used only for navigational purposes. The Naval Observatory at Washington,

D. C., and the naval shipyard at Puget Sound are the only naval authorities authorized to work on these timepieces. You will not be called on to repair chronometers, because the scientific equipment used for checking their rates after repair is not available at ship or shore stations.

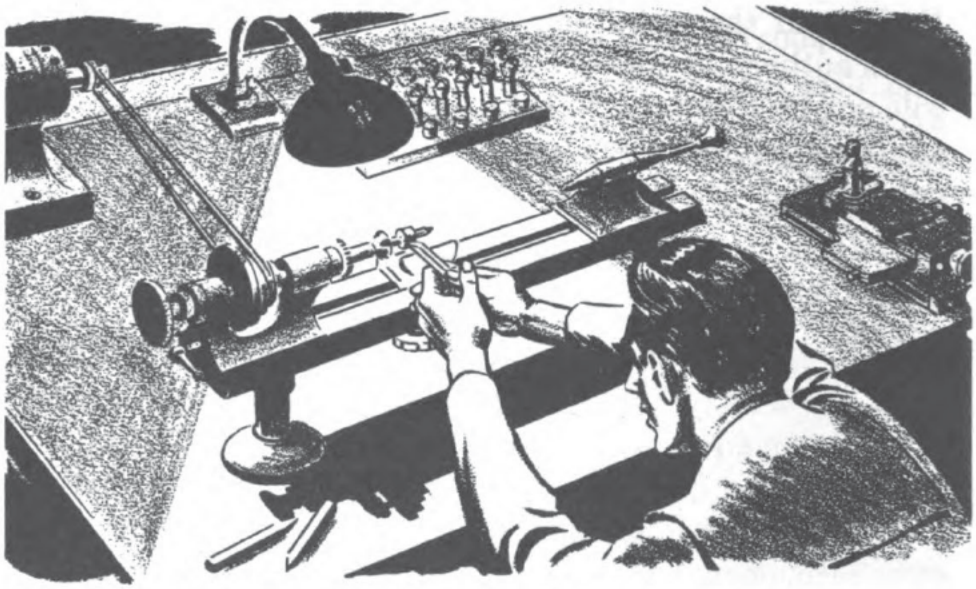
## SUMMARY

This chapter covers the main steps of watch repair: (1) inspection before disassembly, (2) disassembly, (3) inspection after disassembly, (4) cleaning, (5) repairing, and (6) reassembly (with lubrication). You may feel now that the prescribed procedures are quite involved, but once you begin actual overhauling and repairing watches and clocks, you will see that the steps recommended are logical and are planned to simplify your work.

A great deal of information on watch and clock repairing has been presented in this chapter. It will pay you to review it often, in order to fix in your mind the points covered, and particularly the correct steps to use in making the casualty analysis of the Navy comparing watch.

## QUIZ

1. What are the six basic operations of watch repair?
2. When is oiling done?
3. What is the probable cause of the trouble when the stem of a watch pulls out of the case?
4. What is the probable cause of trouble when the watch cannot be fully wound?
5. When the hands of a watch are loose, on either the hour wheel or the cannon pinion, so that they do not indicate the correct time, what repair procedure is needed?
6. What are the probable causes of trouble when a watch runs too slow?
7. What is the best method for removing the hands of a watch?
8. How should a mainspring be inserted into a watch barrel?
9. What repair tools, in addition to those used on watches, are required for Navy clock repair?



# CHAPTER 6

# MAKING AND FITTING WATCH PARTS

## ROLL YOUR OWN

Under normal conditions, the Instrumentman has on hand an adequate supply of standard Navy watch and clock parts. Usually, when you need a new mainspring, balance staff, or sweep second hand to repair, say, an Elgin Timer stop watch, you will have only to take the new part from the parts cabinet. Your stock will be kept up to date because whenever you use a spare part from the cabinet, you will make out a stub requisition for it. Then once a week you will turn these chits into the supply department and draw new parts to replace those that have been used.

There are times, however, when you will have to make watch parts. Natural shortages and factory labor troubles sometimes result in incomplete stocks, or in an emergency period a Repair Ship may not make port for many months, and so be unable to replenish its stock of spare parts. The present-day watch repairer will not be called upon to make any and every kind of new part, as did the civilian watch repairman of the past generation. But to know your trade thoroughly and to qualify for your rating as Instrumentman 2, 1, or Chief, you must be able

to make, as well as install, any of the important watch parts.

Instructions are given below for making balance cocks and click springs, and for replacing broken balance staffs, watch stems, and crystals. The use of jewels in watches is described. The construction of the mainspring and the method of calculating watch trains are explained. There are also instructions for demagnetizing a watch, which is something that every Instrumentman must know.

## MAKING A BALANCE COCK

So that you will know something of the procedure in making small watch parts, the making of a balance cock is described. It will serve as an exercise in filing.

A piece of flat brass is selected, measuring about ¾ inch in length, ¼ inch in width and ¼ inch in thickness, and laid on a piece of cork held in a bench vise. Two pins are inserted vertically into the cork, as shown in figure 69. The cork base is used, because it allows the piece to give and find its own level during the filing operation.

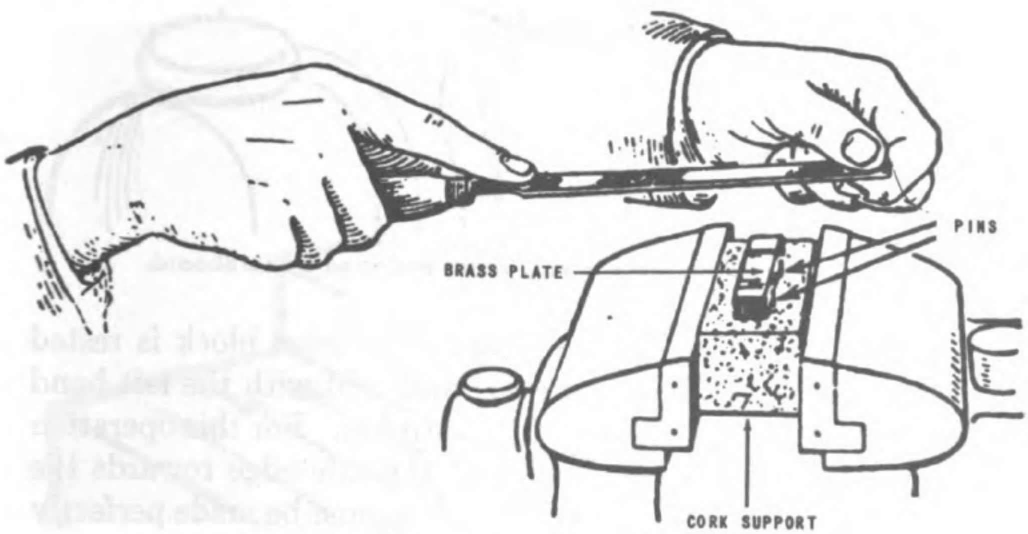



Figure 69.— Filing brass plate on cork support.

The file is held horizontally, as shown, so that an even pressure can be exerted during the entire stroke, and the top surface is filed flat with long, steady strokes. The cutting takes place during the forward movements. The top surface of the brass plate is filed until all marks have been removed, then the piece

is turned over and the other side is filed. When both sides are flat and smooth, the thickness of the piece is measured at several points with a micrometer or vernier caliper to make sure that both surfaces are parallel.

The piece is then locked in a vise, its sides being protected with a small piece of cardboard folded around it (see figure 70); then the sides and edges are squared. This filing work is not as easy as it sounds; it takes a considerable amount of practice to be able to do it correctly.

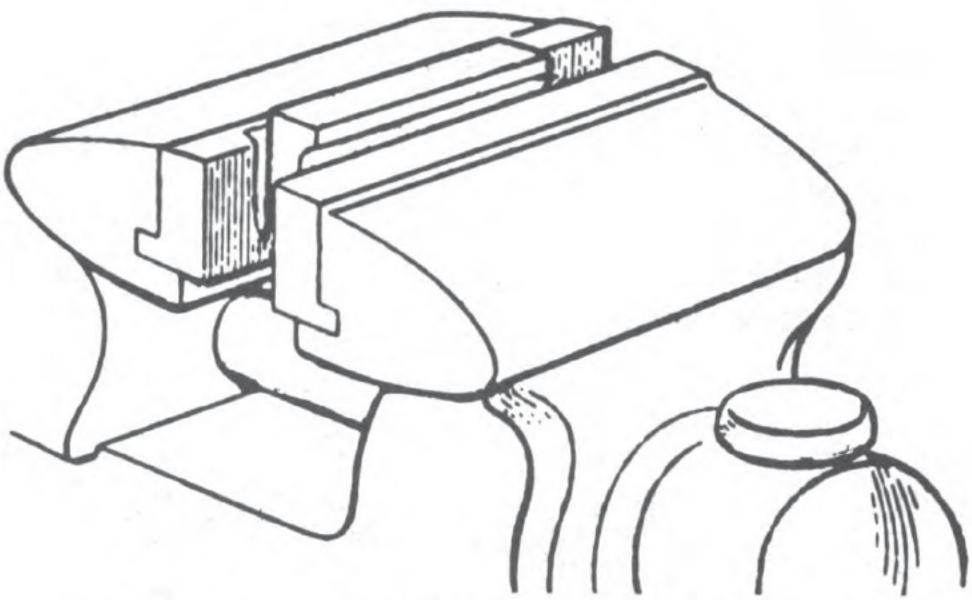


Figure 70. — Brass piece in vise, edges protected by cardboard.

Next a step is filed on the piece. The brass block is rested on the piece of cork (see figure 71) and held with the left hand while the step is filed with slow, firm strokes. For this operation a broad pillar file is used, held with the safe edge towards the newly formed shoulder. The file strokes must be made perfectly straight so that the shoulder edges will not be rounded. About ⅔ of the metal is filed away; then the piece is reversed and turned over, and filed at the other end to about half the depth of the metal. The end is rounded off by further filing.

Normally, the next step would be to drill holes for the screw and the regulator pins and then locate the cap jewel. But since this balance cock is being made mainly for practice in

filing, we will not describe these final operations here. The four flat surfaces should be finished with medium emery buff applied with the same straight strokes employed when filing. This produces on the piece a fine straight grain running in the directions shown by the arrows in figure 72.

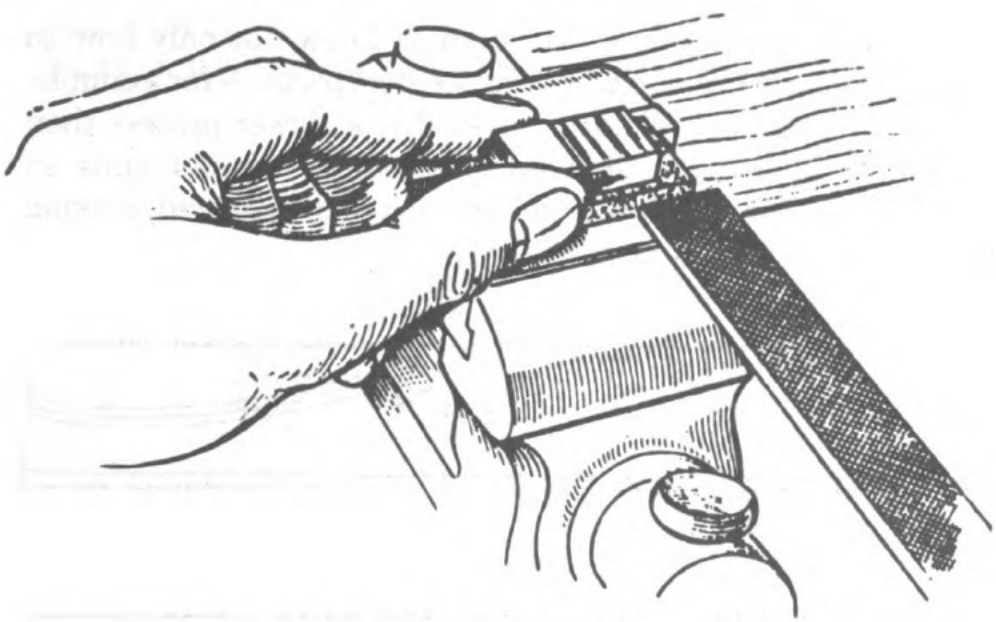


Figure 71. — Filing the step.

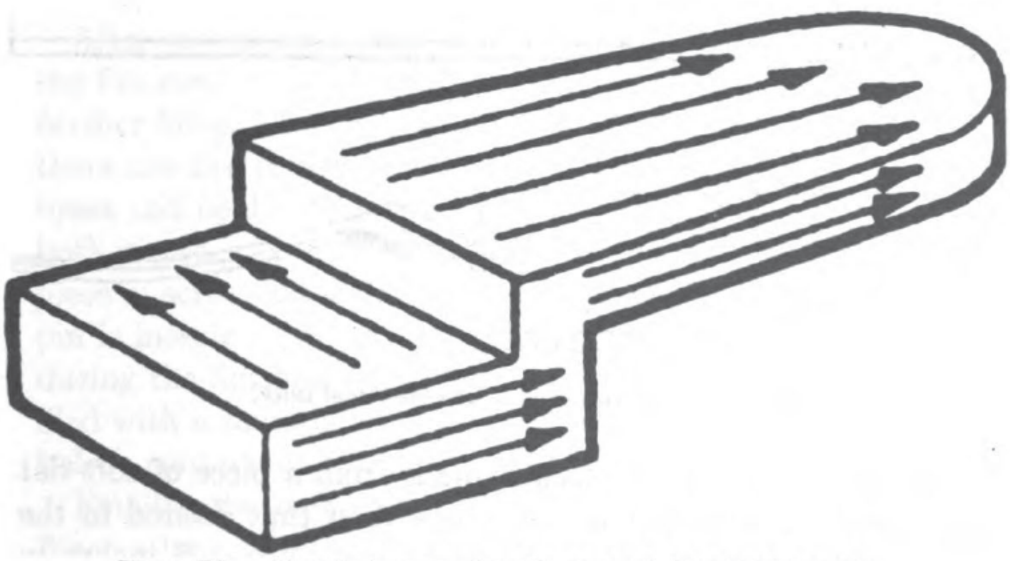


Figure 72. — New balance cock, with arrows indicating the grain.

The emery buff method of finishing is very satisfactory if the brass surface is smooth and can be finished quickly without

rounding the edges. If the surfaces are rough and do not respond to the emery buff treatment, the piece should be finished by stoning it with an India stone dipped in water and used with a circular motion.

## MAKING A CLICK SPRING

In watch repairing, you will need to know not only how to work brass parts but also how to make steel parts — for example, a clock click spring. Working in steel is a slower process than working in brass. The file used for steel work is not quite so sharp. When the steel has been hardened and tempered, making an impression on it is more difficult.

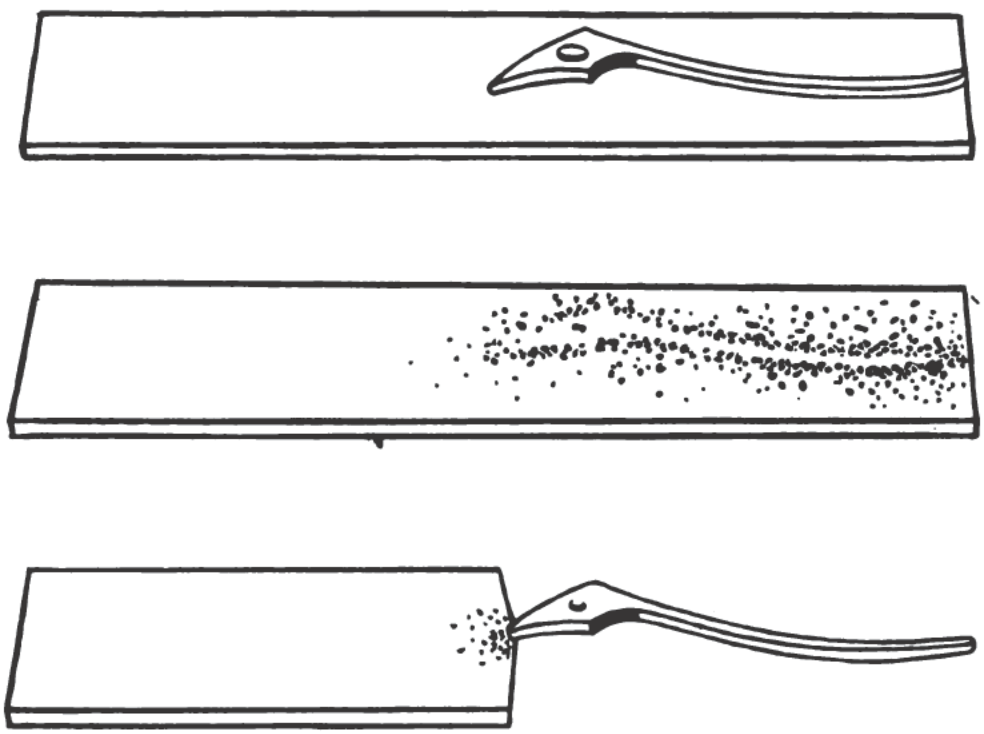


Figure 73. — Making a click from flat steel stock.

The click spring for a clock is made from a piece of soft flat steel having a little greater thickness than that desired in the finished spring. A piece of flat steel stock about 6 inches in length is selected. One end is cleaned with an emery buff and covered with beeswax so that a wax film will be formed. The sample or broken spring is placed on the clean end of the stock,

as shown in figure 73, and the strip is heated until the end supporting the spring turns blue.

Then the flame is removed and the spring is cooled by blowing gently upon it. When this is done, an outline of the sample spring will be etched onto the steel. The new spring is filed to the shape of this outline with several worn round and half round files. The spring is held in pliers and its sides are draw-filed as shown in figure 74 to insure even thickness in the new part.

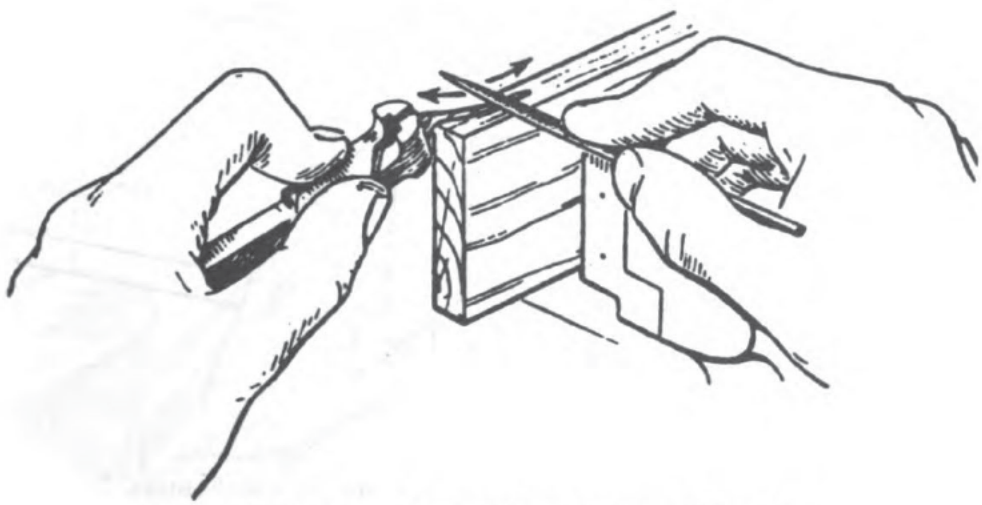


Figure 74. — Draw-filing edges of the new click spring.

After the spring has been filed to shape, it is cut away from the flat steel strip with a screwhead file and then finished off by further filing. To drill the hole for the screw — or two holes if there are two screws — the spring is clamped to a flat piece of brass and held with a pin vise while the hole is drilled through both pieces. This procedure avoids breakage of drills. Next, a piece of soft wood is tightened in a bench vise, and a short brass pin is inserted through the hole in the spring to hold it steady during the finishing operation. (See figure 75). Both sides are filed with a smooth file until they are flat and true. The screw-hole is countersunk to receive the screwhead.

Finally, the new spring should be hardened and tempered. Since a long, thin piece of steel like this may become distorted when plunged into cold oil or water for hardening, the spring should be bound tightly with a thin piece of *binding wire*, with one end bent to act as a handle, before the spring is subjected

to hardening (see figure 76). The wire is taken off after immersion in the oil, and the spring is tempered by heating it to a pale straw color, and allowing it to cool slowly. The bevel on the

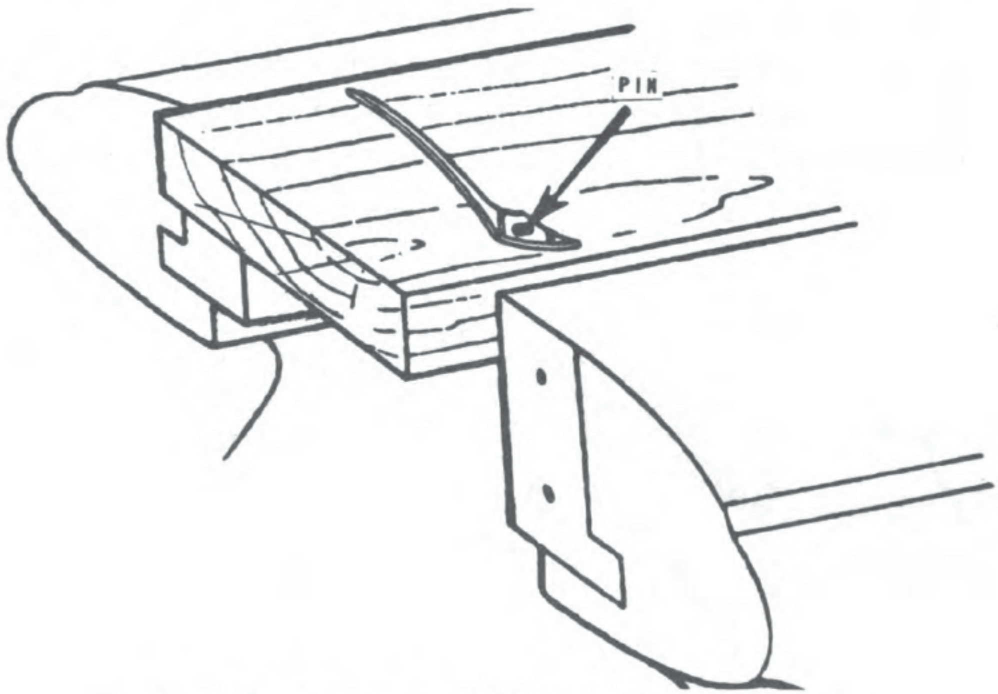



Figure 75. — New spring, pinned to wood block for finishing.

top edge of the spring is burnished with an oval burnisher, and the top edge of the screw hole is chamfered and burnished. The spring, illustrated in figure 77, is then ready for use.

## REPLACING A BROKEN BALANCE STAFF

There are several approved methods of repairing broken or damaged balance staffs. Two methods generally used by Instrumentmen will be described.

The balance assembly is taken out of the movement, and a point is marked on the balance rim to show the relation of the jewel pin and the hairspring stud. This point aids in locating the correct balance position later, during reassembly. After the hairpsring stud screw has been loosened, the hairspring is removed from the balance cock. The roller table is driven off the staff with a roller remover and staking tool. Then one of the two following methods is used to remove the staff:

1. *Turning off the hub.* — To remove a standard *rivet type*

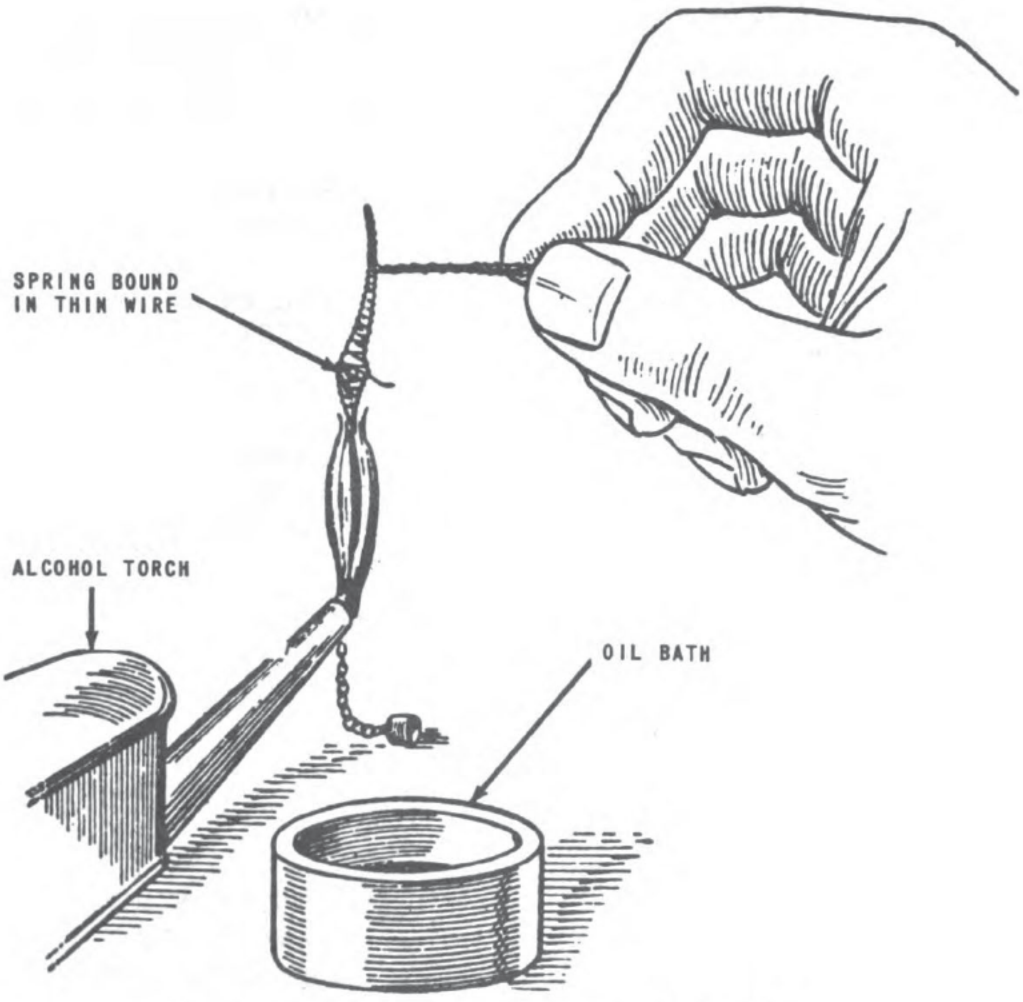



**Figure 76.— New spring bound with wire for hardening.**

**Figure 77.— Finished click spring.**

*balance staff* from its balance wheel, the staff and wheel are chucked in a lathe with the roller shoulder extending from the chuck. A pointed graver is used to cut into the roller seat, as shown in figure 78. This turns off the hub of the staff. As this part is being removed, the graver's edge approaches the balance arm. In figure 79, the graver has just touched the balance arm, allowing the ring of metal which formed the balance seat to drop off. In most cases the balance wheel can then be slipped

off the staff. If the wheel does not come off, and if it cannot be forced off by twisting it with the fingers, the staff and wheel must be, removed from the lathe and separated with a staking

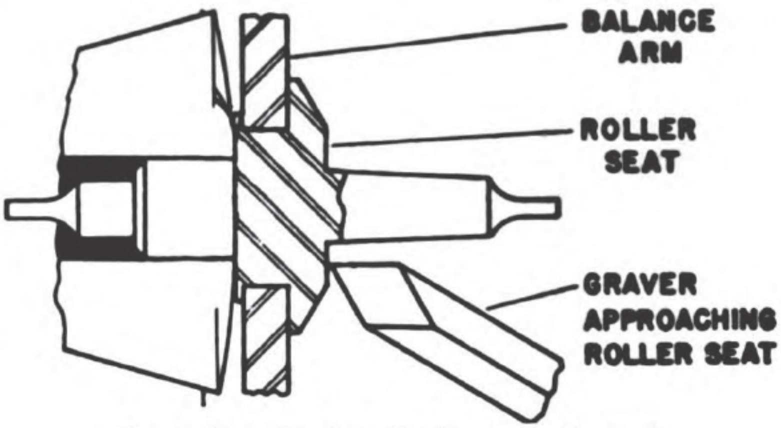



Figure 78. — Turning off roller seat with graver.

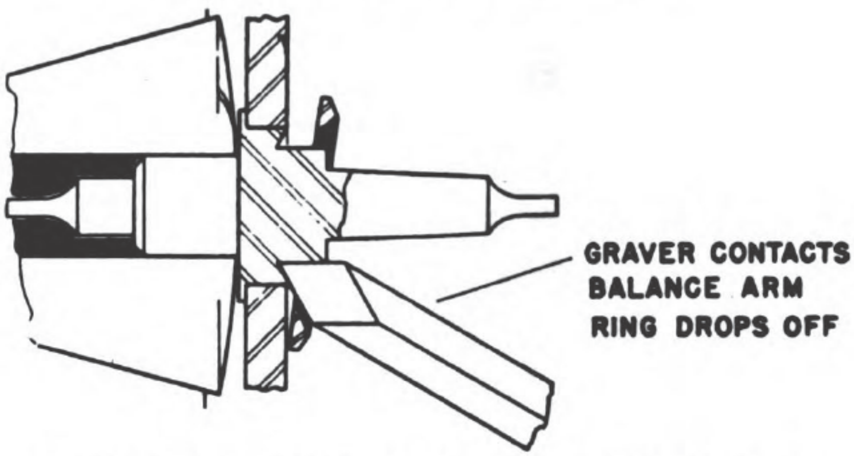



Figure 79. — Ring dropping off when graver touches balance arm.

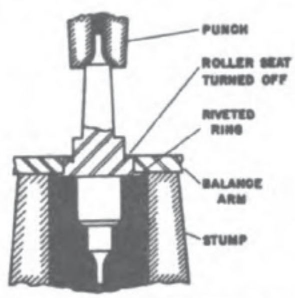



Figure 80. — Removing the balance wheel (rivet-type staff) with staking tools.

tool. The assembly is inserted into a stump having a hole slightly larger than the riveted shoulder of the staff, and the staff is pressed through the balance arm by a punch with a hole

small enough to fit the conical portion of the pivot. (See figure 80). This is standard Navy procedure for removing rivet-type balance staffs. All Navy clocks and Elgin Timers have this type of balance staff.

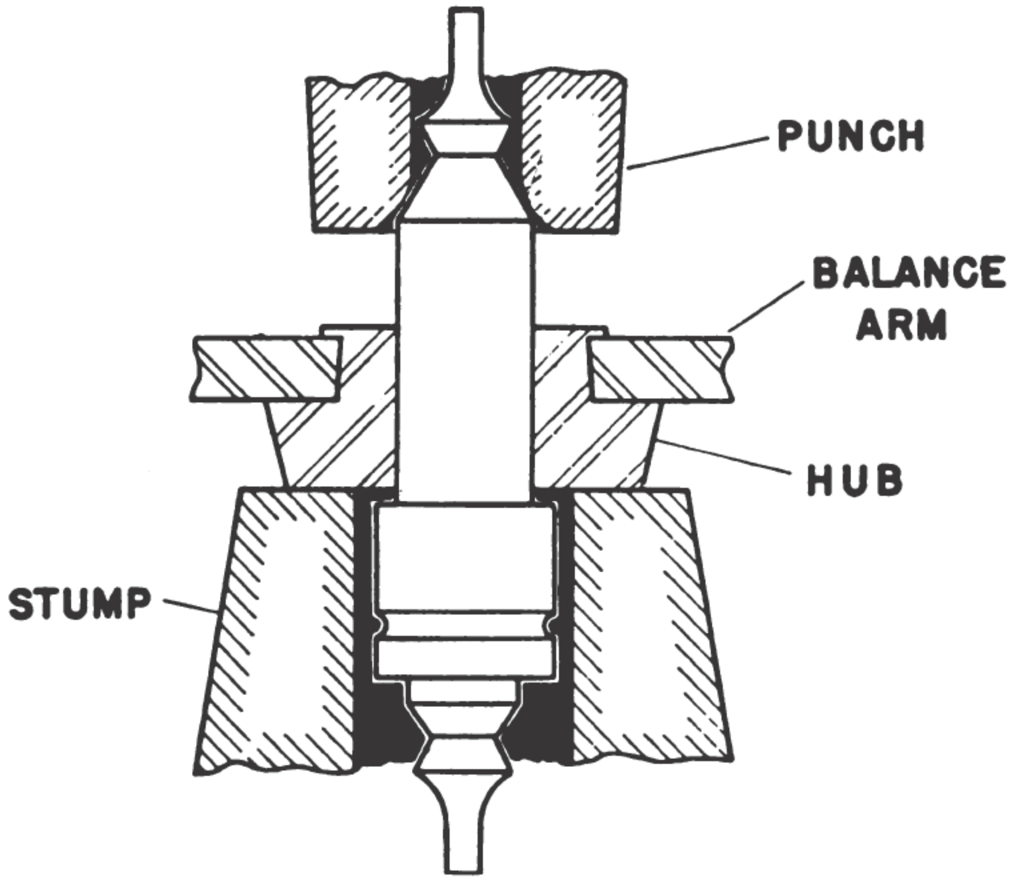



Figure 81.—Removing a friction-fitted staff.

2. *Driving off with staking tool.*—The staff-removal procedure is simpler for a *friction-fitted staff*. The lathe operation is not then required. The staff and arm are placed on a staking stump having a hole slightly larger than the roller shoulder, and a punch with hole large enough to bear on the chamfered portion of the staff (see figure 81) is used to drive the staff off the hub by tapping on it with a pair of tweezers. This is the method used to remove the friction-fitted staffs of Hamilton Comparing Watches.

Whichever of the two methods has been followed in removing the staff, the next step is to replace the assembly in the watch movement. The balance wheel is riveted to the new staff with

the staking tool. The roller table is driven onto the staff with the same tool, and the balance wheel is trued in-the-round and in-the-flat with truing calipers. The wheel is poised by using the poising tool and then, using the calipers again, it is checked for truth. The hairspring is replaced on the balance staff with the staking tool, and the new balance assembly is installed in the watch movement. The final step is to put the watch in beat. (See chapter 7.)

## TIGHTENING A LOOSE CANNON PINION

The cannon pinion should fit with the same amount of friction all around the center wheel post. If you find it is loose, seat it on a tapered round broach, move it slightly forward, and using a small pair of cutting pliers, whose edges have been rounded off, tighten the cannon pinion at its slot. (See figure 82). The

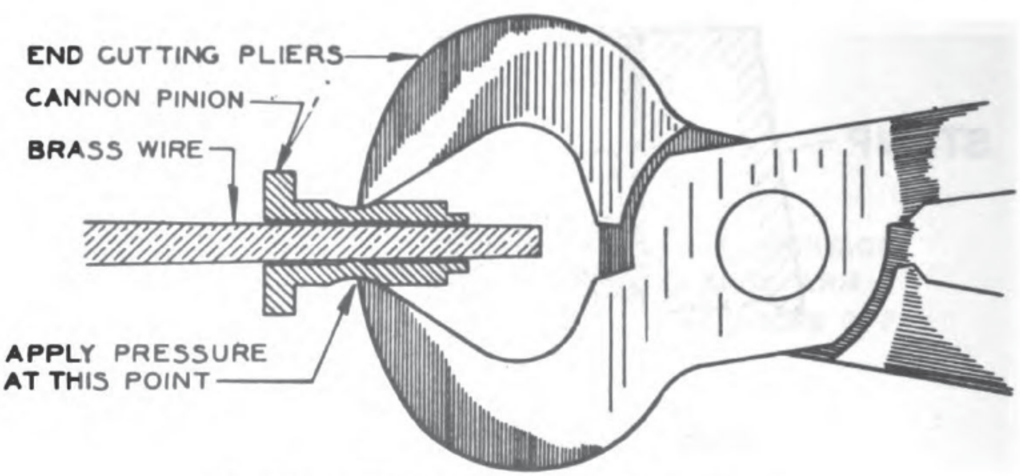



Figure 82.— Tightening a loose cannon pinion.

tension must be sufficient to carry the dial train and the hour wheel, but not so tight as to prevent smooth setting of the hands.

## REPLACING A WATCH STEM

When a stem has become broken or badly worn, it is removed from the watch after the setting lever screw has been loosened. If the old crown is in serviceable condition, it should be unscrewed and saved for use on the new stem.

A new stem is selected from the parts stock and, with the crown screwed on loosely, it is inserted in the watch movement.

New stems are always supplied with extra length so that the correct length for each watch can be determined individually. The threaded end of the stem is shortened with cutting pliers and finished with a file. The stem should be shortened by small amounts, and its length checked often by placing it in the movement, to make certain that too much stock is not being removed. After the stem has been cut to the proper length, any burrs on the threads should be filed off. The square portion of the stem is held in the pliers, and the new crown is screwed on tightly. When placed in the movement again, the stem should be rotated several times, in a clockwise, and a counterclockwise direction to insure freeness of movement and a proper fit.

## INSERTING A NEW WATCH CRYSTAL

Modern Navy watches have plastic crystals that are designed to eliminate breakage. But since these crystals mar easily and occasionally discolor, the Instrumentman must know how to replace them. The tools that he uses consist of a pair of crystal-inserting pliers, six plungers, eight cups (or inserter disks), and a metric rule. These tools are shown in figure 83.

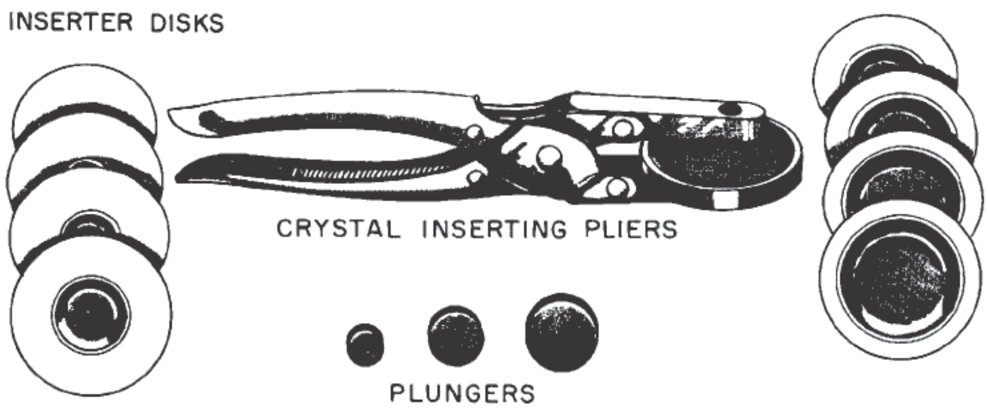


Figure 83.— Watch crystal inserter set.

Before a new crystal is installed, the groove in the bezel should be cleaned with a pointed piece of pegwood, and inspected for dents. The diameter of the opening in the watch bezel is measured with the rule before a crystal is selected; a pocket watch crystal must have a diameter about 2 mm. larger than the bezel opening. Once the crystal size has been determined,

the cup is selected according to the crystal number stamped on the cup face.

The cup and its corresponding plunger are then placed in the special pliers. The beveled side of the new crystal is turned downward over them, and the watch bezel, undercut side down, is placed over the crystal. The pliers are gradually closed with a light pressure.

The plunger makes the crystal cup-shaped, and reduces its diameter. When the size of the crystal has been reduced so that it fits into the bezel, the bezel is rotated to insure a proper seating. The pressure on the pliers is then relaxed until the new crystal is firmly seated in the bezel.

If the curvature of the crystal is not great enough to allow proper freedom for the hands of the watch, the next larger crystal should be used.

## WATCH JEWELS

In 1704 Nicholas Facio, a brilliant Italian scientist-mathematician, first successfully applied jewels to watches, and thereby greatly improved their timekeeping qualities. His method of using jewels as watch bearings consisted of grinding a V-shaped recess into a jewel, then burnishing it into the plate or bridge. Swiss watchmakers quickly recognized the advantages of jeweling and developed it to the present day method.

Jewel bearings are an essential part of modern watches. Jewels reduce friction and wear on pivots and bearings, giving the watch much greater accuracy and a longer life. In fact, the quality of a watch is usually judged by the number of jewels employed in its manufacture.

Most Navy watches have 17 jewels; Navy clocks have 7 or 11 jewels. Since the escapement contains the fastest moving parts, jeweling in that part of a watch or clock is especially helpful in maintaining good performance. Jewel locations vary somewhat in the different makes and types, but they are usually found in the watch as follows:

*a. 7-jewel watches.*

Two balance hole jewels — one at each end of balance staff.

Two balance cap jewels — one at each end of balance staff.

One roller jewel (also called roller pin).

Two pallet jewels.

*b. 9-jewel watches.*

The 7 jewels found in 7-jewel watches, plus a hole jewel at each end of the escape wheel.

*c. 11-jewel watches.*

The 9 jewels found in the 9-jewel watches, plus a hole jewel at each end of the pallet arbor.

*d. 15-jewel watches.*

The 11 jewels found in 11-jewel watches, plus one hole jewel at each end of the fourth wheel staff and one hole jewel at each end of the third wheel staff.

*e. 17-jewel watches.*

The 15 jewels found in 15-jewel watches, plus a hole jewel at each end of the center-wheel staff.

*f. 19-jewel watches.*

The 17 jewels found in 17-jewel watches, plus a cap jewel at each end of the escape wheel arbor.

*g. 21-jewel watches.*

The 19 jewels found in 19-jewel watches, plus a cap jewel at each end of the pallet arbor.

*h. 23-jewel watches.*

The 21 jewels found in 21-jewel watches, plus either a hole jewel at each end of the mainspring barrel arbor, or a cap jewel at each end of the fourth wheel arbor.

For many years, natural sapphires and rubies and small commercial-grade diamonds were used in watchmaking. However, synthetic jewels made by fusing finely powdered aluminum oxide in an oxyhydrogen flame and grinding the blanks accurately to the desired size and shape, are now widely employed in modern watch manufacture. When made with care and properly selected, synthetic jewels give highly satisfactory service as watch bearings.

## Types of Bearing Jewels

Bearing jewels are made either with straight edges for friction setting or with beveled edges for burnished-in setting. The straight-edged jewels are known as friction jewels; the beveled

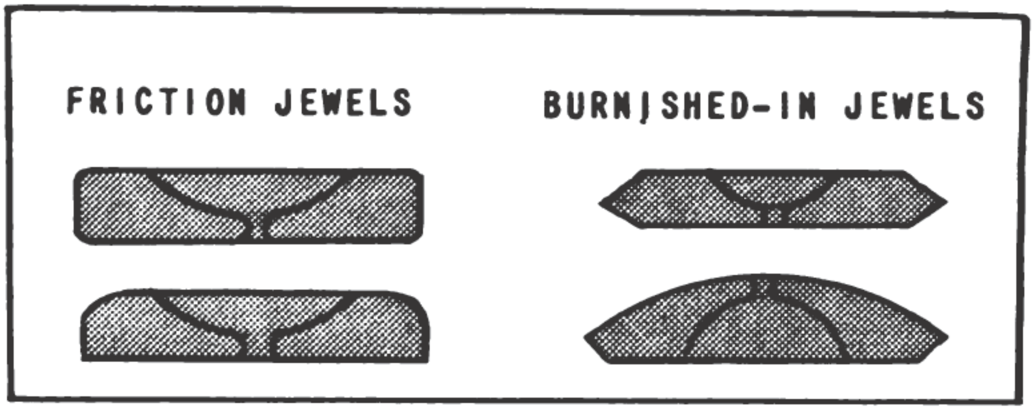


Figure 84.—Friction and burnished-in jewels.

jewels are called bezel or burnished-in jewels. Both types are illustrated in figure 84.

Watch jewels may have curved or flat surfaces. Jewels with curved surfaces are better adapted to use with balance, escape wheel and pallet arbor pivots because of their oiling advantages. Oil, like all other liquids, has a tendency to flow into narrow spaces. For example, if two flat glass plates are held together on a slant so that their edges touch at one side but remain apart at the other, a small quantity of oil placed between the plates tends to run towards the line of contact. This phenomenon is called capillary attraction. This physical law is the basis for the use of curved jewels in watchmaking; it makes the oil stay in the convex jeweled bearings and cling to the pivots until it evaporates.

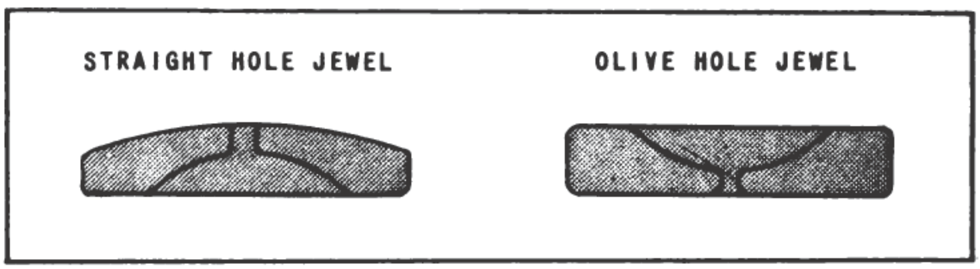


Figure 85.—Straight hole and olive jewel hole.

In jewel bearings, two different types of holes are used—the ordinary straight hole with sharp corners, as shown at left in figure 85, and the olive hole, made by grinding off the sharp corners at both its openings, as shown at right in the same figure.

Balance hole jewels are always backed with cap jewels (also

called endstones), and in watches which have the larger number of jewels the escape wheel and pallet arbor jewels are also designed that way. Figure 86 shows an olive hole jewel and

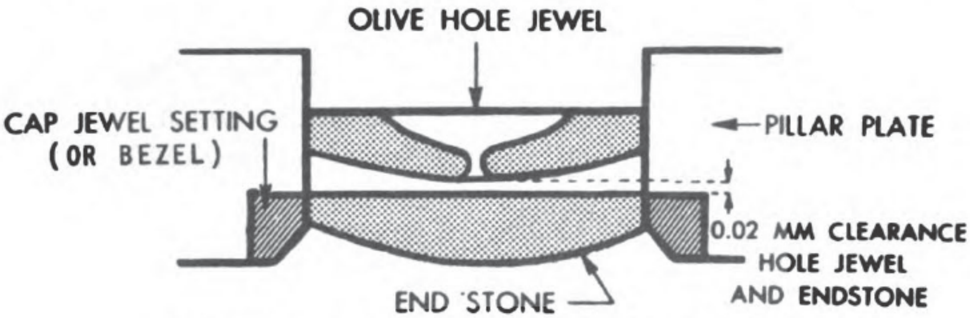



Figure 86. — Olive hole jewel and endstone assembly.

bezeled endstone, with customary clearance of 0.02 mm., as ordinarily assembled in a watch plate. The endstones allow the pivot of the balance or arbor to rotate on its point when the watch is in a horizontal position. The capillary attraction of the oil at the pivot assures good lubrication there as long as the oil supply lasts. If pivots running in settings of this type are properly lubricated when the watch is serviced, the oil supply between the two stones will last at least a year. Once the oil has evaporated, the jewel bearings are in danger of becoming scored.

## MAINSPRINGS

The motive power of the watch is furnished by the mainspring — a long, thin strip of hardened, tempered steel. This spring is wound in the mainspring barrel, with one end hooked to the barrel and the other end attached to the barrel arbor. When the crown is turned in a clockwise direction, the barrel arbor is rotated and the mainspring is wound around it. The strength of the mainspring is at its maximum when the spring is completely wound up, but the power decreases irregularly during the course of the day. After from 36 to 40 hours, the mainspring has become completely unwound and must be wound up again for the next cycle.

The mainspring's decrease in power while the watch is running is clearly shown by the chart in figure 87. Point *A* indicates the strength of a fully wound spring. After a half-revolution of the

barrel, about $3\frac{1}{2}$ hours, (*B*), a considerable amount of power has been lost, and after 24 hours (*C*), the power has been reduced to about one-half its initial value.

## The Mainspring Construction

When a mainspring must be replaced, it is highly important that the new spring be of the proper size and strength. Whenever possible, broken or "set" mainsprings (see figure 88) should

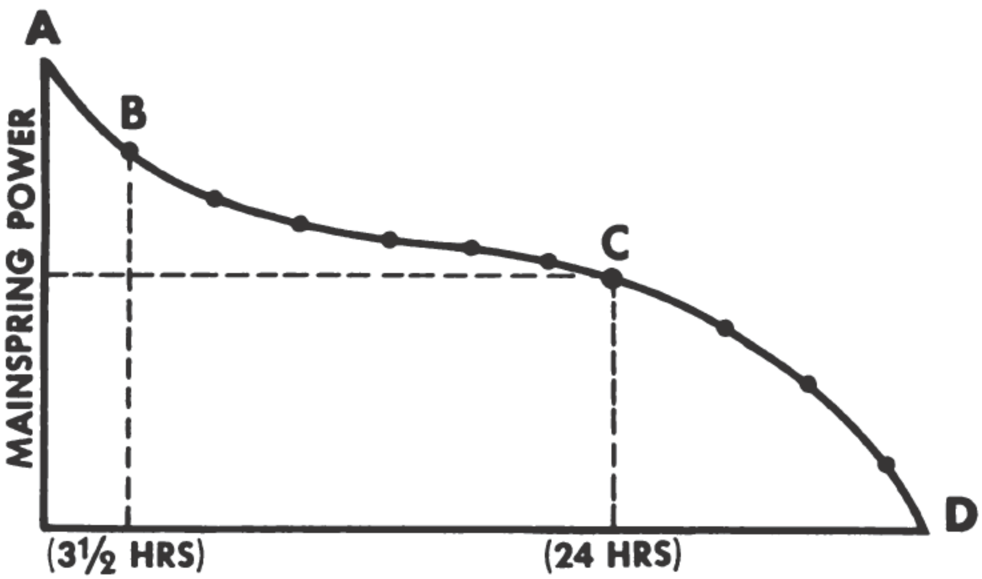



Figure 87.—Chart indicating decrease in mainspring power.

be replaced with a new genuine factory made spring of correct resiliency as specified by the maker of that particular watch or clock. When it is not possible to do this, the proper thickness and length of the mainspring must be calculated.

A spring that is *too thick* will give too much power (since the thickness of a spring determines its strength) and will speed up the motion of the watch beyond safe limits. The jewel pin will then bank against the pallet fork, and the regulation of the watch will be seriously impaired. On the other hand, if the spring is *too thin* it will be unable to keep the watch running. After the watch runs for a few hours, the tension will be too weak to give the balance wheel a good running motion and the watch will stop.

A spring that is *too long* will not have space enough in the barrel to unwind fully, and will not run its full time. A spring that is *too short* will not have enough coils to unwind at the proper rate, so it will unwind quickly and the watch will not run its maximum number of hours.


Figure 88.—Perfect and "set" mainsprings.

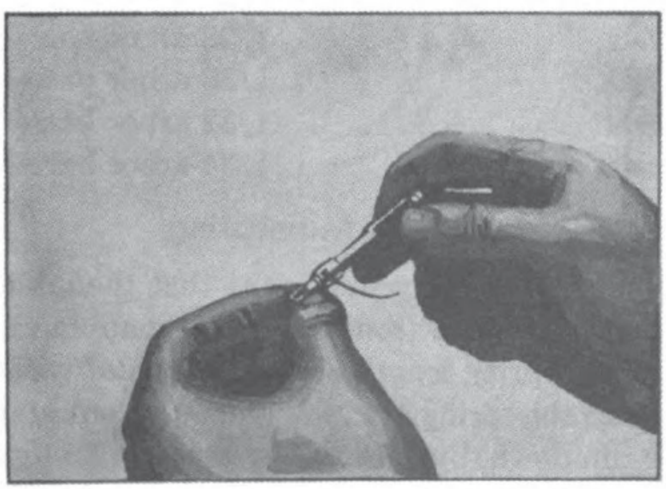


Figure 89.—Using mainspring winder to insert and eject mainspring.

When the proper thickness and length of the mainspring has been determined, it should be inserted into the barrel with a mainspring winder, *not with the fingers*. These winders are made in different sizes to accommodate the various barrels. Movable jaws on the winder provide extra flexibility in increasing or decreasing the diameter of the winder's barrel. (See figure 89).

## Calculation of Dimensions

The thickness and width of mainsprings are measured in millimeters. The watchmaker's micrometer will measure these dimensions very accurately. If a micrometer is not available, a Dennison mainspring gage may be used; the thickness and width of a new mainspring are measured with this tool in terms of sizes of commercially available mainspring replacements.

## Thickness of Mainspring

When it is necessary to determine the thickness of a mainspring for use with a given barrel, and no sample or replacement data is available, the thickness can be roughly calculated from the table given below. The mainspring thickness is given in terms of the arbor diameter. As would be expected, a thinner, weaker mainspring is required as the quality of the watch improves with the number of jewels in the movement.

### Guide to Mainspring Thickness (mm.)

(*Pocket watches*)

| | |
|---|---|
| 7–15 jewels | 1/26 arbor barrel diameter |
| 15–17 jewels | 1/28 arbor barrel diameter |
| 17–19 jewels | 1/30 arbor barrel diameter |
| 19–21 jewels | 1/32 arbor barrel diameter |
| 21–23 jewels | 1/34 arbor barrel diameter |

## Length of Mainspring

As stated above, it is very important that the mainspring be of correct length. If data from the watch manufacturer is not at hand, the mainspring length can be *calculated* without much difficulty. Since the spring occupies an equivalent area whether wound up or run down, by subtracting the area occupied by the barrel arbor from the area of the barrel and dividing the remaining area by 2, we can find the amount of space that the spring will occupy. The length can then be determined by dividing that amount of space by the spring's thickness. The steps in this calculation have been combined into a simple formula:

$$L = \frac{\pi (R^2 - r^2)}{2t}$$

When $L$ = length of mainspring
$R$ = radius of barrel chamber
$r$ = radius of arbor
$t$ = thickness of spring
$\pi$ = 3.1416 (a constant value)

When ESTIMATING the length of a mainspring, keep in mind the correct space relations inside a mainspring barrel. The unwound mainspring should occupy slightly less than one-half of the distance between the barrel arbor and the inside surface of the barrel. When wound, the spring covers a little more than one-half the distance between the barrel arbor and the inside of the barrel. The space occupied by the unwound spring and the space which it will occupy when coiled are of course, equal in area. (See figure 90).

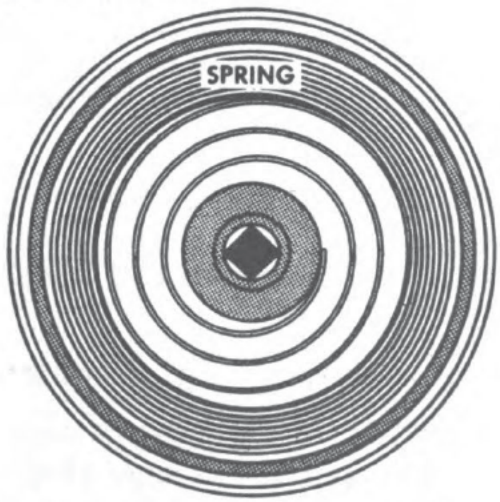



Figure 90.—Barrel showing space occupied by mainspring.

When replacing a spring, if you find that it occupies more than one-half the barrel space, break off the outer end and rewind the spring into the barrel.

A spring of the correct length should have 11 to 13 coils. More than the right number of coils results in more friction and shortens the running period of the watch.

## THE MAIN TRAIN

Watches have two trains; the main or time train, and the dial train. The main or time train changes the *slow* motion of

the mainspring barrel into a *fast* motion, causing the wheel carrying the minute hand to make one turn in the same time that the escapement makes the required number of impulses or beats. In pocket watches this number is usually 18,000 per hour. The dial train, on the other hand, changes a *fast* motion into a *slow* one, and governs the distance that the hour hand travels to one turn of the minute hand.

## The Number of Turns of a Pinion

The number of turns made by a pinion geared to a wheel is found by dividing the number of teeth in the wheel by the number of leaves in the pinion. Suppose, for example, that a wheel with 72 teeth meshes with a pinion of 12 leaves. If we call the wheel $B$, and the pinion $c$, this relation may be expressed as follows:

$$\frac{B}{c} = \text{number of turns of the pinion}$$

Substituting their numerical values, we have:

$$\frac{72}{12} = 6 \text{ turns of the pinion to 1 [illegible] the wheel}$$

## The Number of Turns of a Complete Train

Most watches contain five wheels, as shown in figure 91. The mainspring barrel and the escape wheel are included in this number. In order to simplify the calculations which follow, we shall identify these five wheels, and the pinions of the train wheels by letters:

| | |
|---|---|
| $B$ = barrel or first wheel | $c$ = center or second pinion* |
| $C$ = center or second wheel | $t$ = third pinion |
| $T$ = third wheel | $f$ = fourth pinion |
| $F$ = fourth wheel | $e$ = escape pinion |
| $E$ = escape wheel | |

*Notice that $c$ really indicates the first pinion; but since a pinion is usually given the same name as the wheel of which it is a part, this is called the second or center pinion. We will use these capital and small letters to denote the number of teeth of these wheels and the number of leaves of the pinions.

A modern watch train often has the number of wheel teeth and pinion leaves shown below:

$$\frac{B}{c} = \frac{72}{12} = 6$$

$$\frac{C}{t} = \frac{80}{10} = 8$$

$$\frac{T}{f} = \frac{75}{10} = 7\tfrac{1}{2}$$

$$\frac{F}{e} = \frac{80}{8} = 10$$

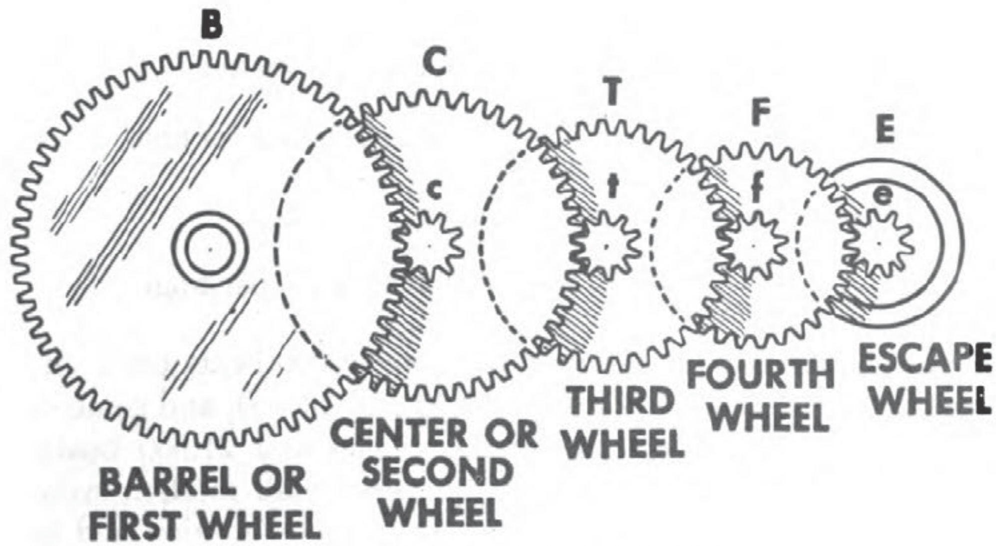



Figure 91. — The main or time train.

Multiplying the numbers 6, 8, $7\frac{1}{2}$, and 10 together gives 3,600, the number of turns the escape wheel makes to one turn of the barrel. Dividing 3,600 by 6 (the number of turns the center wheel makes to one turn of the barrel), we get 600. This number, 600, represents the number of turns made by the escape wheel *in one hour*, since the center wheel which carries the minute hand always makes one turn every hour. Our calculations here will all be based on one turn of the center wheel (one hour of time), and is expressed by the following formula:

$$\frac{C \times T \times F}{t \times f \times e} = 600 \text{ (number of turns of escape wheel per hour)}$$

In watches which register seconds, the fourth wheel carries the second hand. That means that the fourth wheel must make 60 turns to one turn of the center wheel. Therefore:

$$\frac{C \times T}{t \times f} = \frac{80 \times 75}{10 \times 10} = 60 \text{ (number of turns of fourth wheel per hour}$$

## The Number of Beats

The escape wheel in most watches contains 15 teeth. Since each tooth delivers two impulses, the first impulse to the receiving pallet and the second to the discharging pallet, the escape wheel delivers to the balance twice as many beats as it has teeth. For the beats of a watch the formula reads:

$$\frac{C \times T \times F \times 2 \times E}{t \times f \times e} = \text{Number of beats per hour}$$

Using the numerical values, we have:

$$\frac{80 \times 75 \times 80 \times 2 \times 15}{10 \times 10 \times 8} = 18{,}000 \text{ beats per hour}$$

Not all watches are designed to make 18,000 beats per hour; some of the older models make 16,200 and 14,400, and some of the new, thin wrist watches make 19,800 and 21,600 beats. The faster trains are used in some very small modern wrist watches, primarily to give the balance a faster motion and so overcome the effect of their thinner, weaker balance springs. However, these conditions are not encountered in standard Navy watches.

## Calculating the Number of Teeth and Leaves of Missing Wheels and Pinions

Occasionally the Instrumentman receives a watch of an unfamiliar make with one of the wheels missing from its train. He must therefore know how to calculate the number of teeth and leaves in wheels and pinions which are missing, if he is to repair such a watch. The number of teeth in a missing fourth wheel, for example, would be determined as follows:

$$\frac{80 \times 75 \times F \times 2 \times 15}{10 \times 10 \times 8} = 18{,}000$$

Here $F$ represents the number of teeth in the missing fourth wheel.

$$225\,F = 18{,}000$$

$$F = 80 \text{ (number of teeth in fourth wheel)}$$

Or suppose the third pinion is missing, and the Instrumentman must determine the number of leaves.

$$\frac{80 \times 75 \times 80 \times 2 \times 15}{t \times 10 \times 8} = 18{,}000$$

Here $t$ represents the number of leaves on the missing third pinion.

$$\frac{180{,}000}{t} = 18{,}000$$

$$18{,}000\,t = 180{,}000$$

$$t = 10 \text{ (number of leaves of third pinion)}$$

## DEMAGNETIZING A WATCH

The watch repairman must understand why watches become magnetized and must know how to remove magnetism from the watches that he repairs.

In your basic Navy training course, ELECTRICITY, NavPers 10622, you studied magnetism. You learned that when a piece of iron or steel is placed in a magnetic field, the molecules shift around so that all the south ends point one way and all the north ends point the other way, and the piece becomes magnetized. Since watches and clocks employ steel in the mainspring, winding mechanism, and pinions, they are always susceptible to magnetism. However, magnetization of these parts does not seriously affect the rate of a watch. A magnetized mainspring is not a serious defect. Although its coils occasionally may stick together, the tension of the mainspring is so powerful that it minimizes this difficulty.

However, if a steel hairspring, roller, and fork become magnetized, the accuracy of the watch will be seriously affected. In such cases the coils of the hairspring may stick together

momentarily or touch the balance arm occasionally when the watch is held in a certain position, and so cause erratic timing. If strongly magnetized, the hairspring will be attracted to the balance arm of the conventional bimetallic type (see figure 92), and may cause the watch to stop.

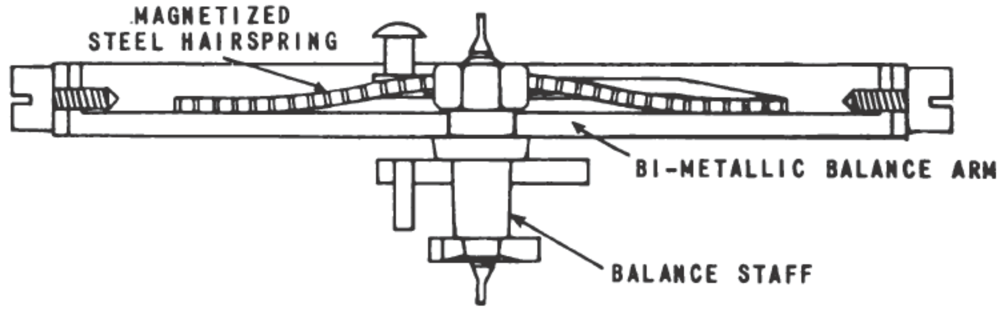



Figure 92.—Strongly magnetized steel hairspring attracted to bimetallic balance arm.

In some modern watches, the balance arm is made of a solid, nonferrous, monometallic metal, and the hairspring is made of a special steel alloy. This type of hairspring is impervious to temperature changes and corrosion and resists the magnetic effect. Such a hairspring cannot become permanently magnetized; the attraction between the balance arm and hairspring is eliminated and the hairspring always retains its normal position (figure 93). Although the watch may stop if brought into a powerful magnetic field, it will run when removed from that vicinity, and can be rated, even though all its steel parts except the hairspring have become permanently magnetized.

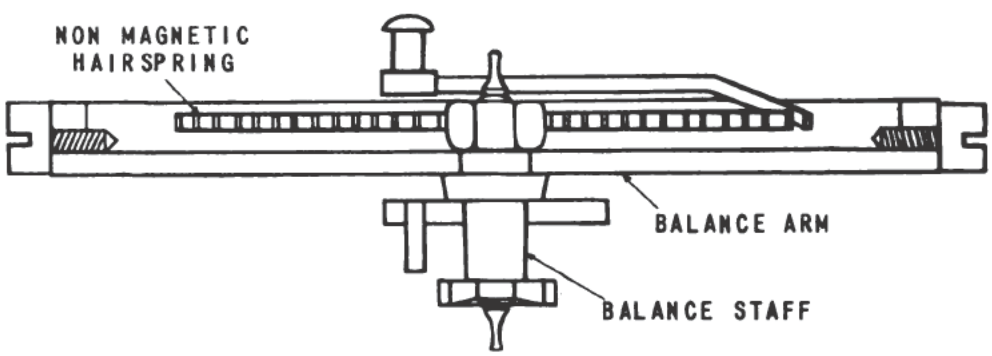



Figure 93.—A nonmagnetic hairspring always retains its normal position.

ALTERNATING CURRENTS do not greatly affect watches and clocks because their magnetic fields are constantly changing in

direction and intensity. They are continuously reversing their polarity, usually at the rate of about 60 times per second.

DIRECT CURRENT has a very decided influence upon the iron and steel parts of a timepiece, because its magnetic effect lines up the molecules permanently. On shipboard, for example, the watch always becomes magnetized when it is brought close to the ship's degaussing gear or goes through a DEPERM operation. Normally, of course, clocks and watches are taken off the ship before deperming is begun.

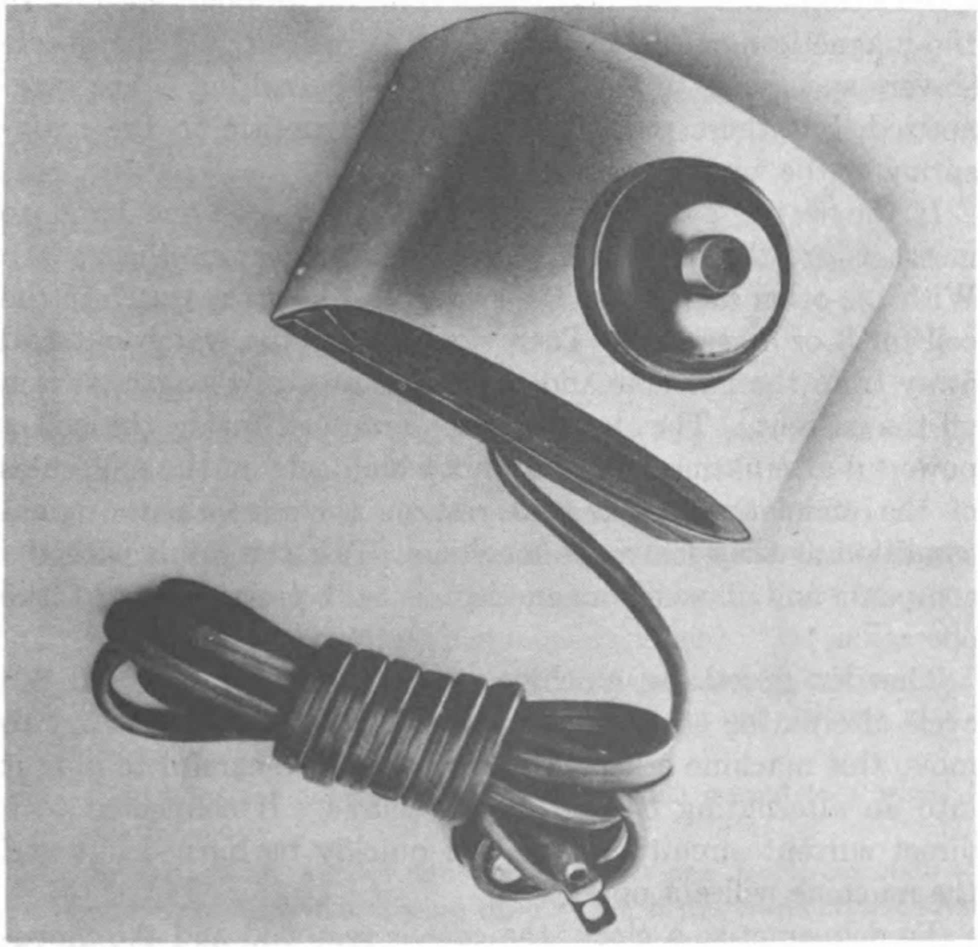


Figure 94. — Demagnetizing machine.

From the above discussion, you know how and why a watch becomes magnetized; now you will understand the demagnetizing procedure.

Every watch that comes into the shop for repair (except watches of the nonmagnetic type) should be tested first for

magnetism. Remove the back and place a small compass on the top of the balance cock, directly over the upper balance endstone. If the watch is magnetized the compass needle will vibrate back and forth because of the effects of the moving parts. The needle may sometimes make a complete revolution and spin around its axis rapidly. This indicates a magnetized hairspring; the watch is then said to be magnetized.

If the needle remains stationary, tap the compass lightly with the tweezers, then slowly twist the movement around in a horizontal plane. The needle will continue to point steadily to the magnetic north if no magnetism is present. If the needle shivers and seems to stick at times, the hairspring is not magnetized, but there probably is some magnetism in the mainspring or the winding mechanism.

If the watch is found to be magnetized, use one hand to insert it into the coil of the demagnetizing machine (figure 94). With the other hand press the switch and hold the watch in the coil for 3 or 4 seconds. Then slowly draw the watch out and away from the machine and when it is at arm's length, switch off the current. The demagnetizer produces inside the coil a powerful alternating magnetic flux which acts on the molecules of the magnetized parts and returns them to their original condition as they leave the machine. Test the result with the compass, and if some magnetism is still present, repeat the operation.

The demagnetizing machine operates only on 115-volt 60-cycle alternating current. Should you ever find it necessary to move this machine about the ship, always be careful to plug it into an alternating current power source. If connected to a direct current circuit the coil will quickly be burned out and the machine will not operate.

To demagnetize a clock, the case is removed and the movement inserted for 3 or 4 seconds in a large demagnetizing coil. If such a coil is not available, the clock must be disassembled and its steel parts demagnetized individually.

## SUMMARY

This chapter covers some of the simpler parts of the watch

repair work that the Instrumentman may encounter. Although replacement parts are usually available, there are times when you will need to know how to make these parts. The operations described are the elementary repair jobs. As you advance in rating, you will learn how to do the more complex repairs, such as making balance staffs and barrel arbors, bending hairsprings and adjusting escapements.

## QUIZ

1. What is draw filing, and how is it done?
2. How is a newly fabricated steel spring hardened and tempered?
3. How is a broken balance staff removed?
4. How may a loose cannon pinion be tightened?
5. What is the procedure for replacing a watch stem?
6. When were jewels first successfully applied to watches, and by whom?
7. Name the jewel locations in a 7-jewel watch.
8. Name the jewel locations in a 17-jewel watch.
9. What are FRICTION jewels?
10. What is the customary clearance between a hole jewel and an endstone jewel?
11. How many turns has a watch mainspring of correct length?
12. What results when a mainspring that is too long is installed in a watch?
13. What is the purpose of the main or time train in a watch?
14. What is the purpose of the dial train in a watch?
15. Does the power of a mainspring decrease regularly or irregularly during the course of the day? What is the approximate rate of decrease?
16. How may the number of turns of a pinion geared to a wheel be determined?
17. In a standard watch train (18,000 beats per hour), calculate the number of teeth in a missing third wheel, if the barrel or first wheel, center or second wheel, fourth wheel and escape wheel have 72, 80, 80 and 15 teeth, respectively, and the center or second pinion, third pinion, fourth pinion and escape wheel have 12, 10, 10 and 8 leaves, respectively.
18. How can you detect magnetism in a watch?
19. How may a watch be demagnetized?

## CHAPTER 7

# ADJUSTING THE ESCAPEMENT

## NO ROYAL ROAD TO KNOWLEDGE

Our study of watch repairing has now advanced to the point where you have sufficient background to undertake the study of the escapement. From this point on, you will see the truth of the old saying, "There's no royal road to knowledge," because to learn watch repairing thoroughly you must understand each basic principle, step by step, as it is presented. However, once you have mastered the theory of the escapement, you will not only experience great personal satisfaction, but you will be well on the road to becoming an expert watch repairman.

## PURPOSE OF THE ESCAPEMENT

The escapement allows the power of the mainspring to be transmitted intermittently from the train to the balance, where the energy is used up at a uniform rate. The successive movements of the different escapement parts were described in chapter 2. The balance is the time-keeping element of the

watch. The rate of the watch, i.e., the time it loses or gains in a given period of time, depends on the period of oscillation of the balance wheel. The mainspring power is arrested and released five times per second, due to the locking and unlocking action of the escape wheel teeth on the pallet stones.

## RELATION OF BALANCE WHEEL TO ESCAPEMENT

If the mainspring power is exhausted and exerts no force on the escape wheel, the hairspring will hold the jewel pin directly over the line of centers of the escape wheel, pallet, and balance. The impulse face of the escape wheel tooth will be in contact with the impulse face of the *R* stone. When power is applied to the escape wheel, it will move in a clockwise direction, causing the *R* stone to be raised; the fork will rotate on its arbor, making the fork slot move along a curved line. The inside wall of the fork slot will strike the jewel pin on its round side, thereby giving an impulse to the balance wheel.

Because of the resistance of the hairspring and the inertia of the balance wheel, the jewel pin will be moved only a short distance by this initial impulse, but the impulse will be completed and the escape wheel will proceed to lock itself on the *L* stone. While the escape wheel is locked and the fork is held against the banking pin $P_1$ (Figure 95) by the "draw," the jewel pin leaves the fork slot and moves back over the short distance mentioned above, because of the resistance of the hairspring and its tendency to bring the jewel pin back to the line of centers. (The draw is the force that holds the fork against the banking pin while the jewel pin is detached from the fork slot.) As the jewel pin is returned, it enters the fork slot and pushes the fork with enough force to unlock the escape wheel from the pallet stone. A stronger impulse then takes place, this time from the *L* stone. The escapement and balance are now gaining momentum, and the inertia is being overcome. On this impulse the jewel pin will be driven a greater distance away from the line of centers. The conditions of UNLOCKING, IMPULSE, and DROP have taken place on the *L* stone; the fork now rests against the banking pin $P_2$ with the escape wheel locked on the *R* stone.

As the jewel pin returns from each successive trip it enters the fork slot, unlocks the escape wheel, receives its impulse, leaves the fork slot and finally reaches the point where it travels about 270 degrees, or three fourths of the circular distance about the balance axis.

## EXAMINING THE ESCAPEMENT

The watch repairer must know how to examine the escapement for defects before he attempts to change any of the conditions that he finds. Every escapement is carefully matched at the factory; it would be most unusual to find a defective escapement in any well-known make of watch. Therefore, the repairing or adjusting of the escapement will be necessary in service only when the watch has met with some accident. The steps taken at the factory to match an escapement are given below. Follow these steps carefully, using a size-16 watch as a guide. When you understand this procedure fully you will know how to adjust the escapement of a watch. Figure 95, which shows the pallet, fork, and roller action combined, will help you understand many of the common terms in the watch and clock trade.

*Banking to the drop.* — In a Hamilton comparing watch No. 2974B, with the balance removed, the banking pins are first turned inward with a screw driver so that they will be as close as possible to the line of centers. The fork will now rest against one of the pins, being held there by the power of the mainspring transmitted through the train wheels to the impulse faces of the escape wheel teeth and the pallet stones. Now, holding the watch in the left hand with the dial side down, insert the screw driver in the screw of the banking pin upon which the fork rests, and turn this screw so that the eccentric pin will move *away* from the line of centers. Observe the movement of the impulse face of the escape wheel tooth across the impulse face of the pallet stone. As soon as the impulse face of the escape wheel tooth drops off the pallet stone, another tooth of the wheel should lock itself on the other stone (assuming that it has a sufficient amount of lock). The lock should be about

1/8 to 1/10 the width of the impulse face of the pallet stone. You will have to use a loupe to observe the action of these parts accurately.

It is important that the lock be examined at the same instant as the drop. Note that the location of the banking pins is determined by the position of the pallet stones.

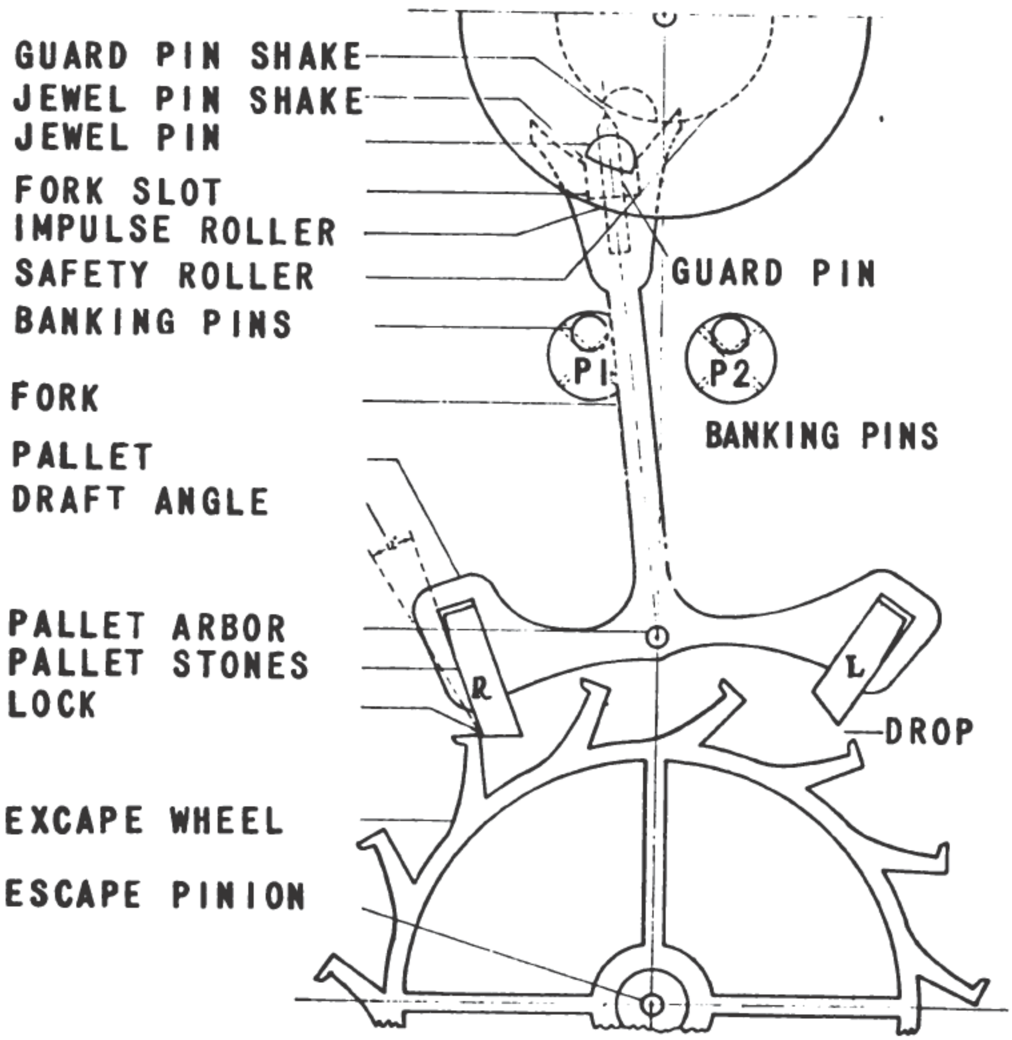



Figure 95. — Pallet, fork, and roller action combined.

The fork should then be moved so that it will rest against the other banking pin, and the action of the escape wheel tooth should be examined. The fork should be moved back and forth and its action observed, until the escape wheel has made one complete turn. The fork is now said to be BANKED TO THE DROP. In this condition the fork will move an equal

distance in each direction from the center line. BANKING TO THE DROP must be thoroughly understood, since it is an important factor in locating errors in the escapement.

Now place the balance, without the hairspring, in the movement and, holding the watch firmly in the left hand with the thumb and second fingers, move the balance very slowly with the first finger of the right hand so that the jewel pin will engage the fork slot. The jewel pin will move back and forth from one banking pin to the other and permit the escape wheel to turn. Study carefully the escapement action at the instant when the escape wheel tooth drops off the pallet stone, holding the balance in that position without movement so as to observe the following:

(1) Lock; (2) Drop; and (3) Jewel pin shake.

*The lock.* — This is the length of pallet stone surface in contact with the escape wheel tooth at the time of drop. It causes a tooth of the escape wheel to come to rest on the locking face of a pallet stone, where it is held securely until it is unlocked by the return trip of the jewel pin. As stated above, the lock should be about $\frac{1}{8}$ to $\frac{1}{10}$ the width of the impulse face of the pallet stone.

*The drop.* — This is the distance between the locking corner of an escape wheel tooth and the pallet stone when one tooth drops from one pallet stone and another locks on the other pallet stone. It should be equal on both sides, and great enough to secure perfect freedom of the escape wheel. When the escape wheel is locked on the *R* stone with the fork resting on the banking pin, and the distance between the *L* stone and the wheel is so close that it will not permit the *R* stone to be unlocked, we have the condition known as CLOSE OUTSIDE. When the escape wheel tooth is locked on the *L* stone with the fork against a banking pin, and when the distance between the *R* stone and the escape tooth that has just passed the *R* stone is so close that it will not permit the *R* stone to be unlocked, we have the condition known as CLOSE INSIDE. The corrections for these two conditions will be considered later in the chapter.

*Jewel pin shake.* — The jewel pin shake should be tried by touching the fork lightly with a needle or other small fork tool.

The point of the fork slot will then be forced against the jewel pin, and when the fork is released, the draw will cause the fork to return to the banking pin. With practice you will be able to observe the jewel pin shake, or clearance, at two places — at the end of the fork and at the lock. Now touch the fork with

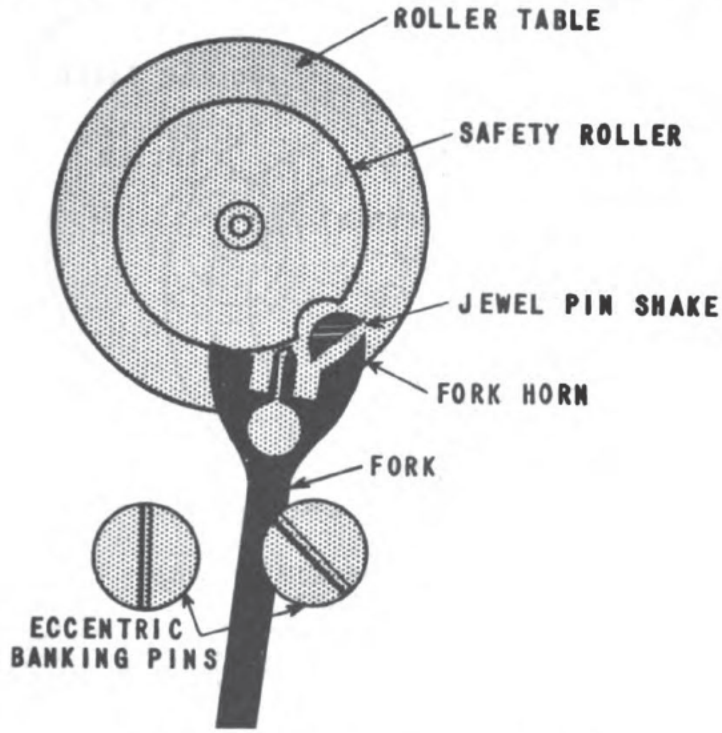



Figure 96. — Correct jewel pin shake.

the fork tool and press the fork against the jewel pin. By looking carefully at the lock you will notice that it has been reduced, and that when you release the fork the draw will pull the *R* stone back to full lock again. This test is a very important one. Practice it until you can do it quickly and surely.

The jewel pin shake should be slightly less than the lock, and should be tried at the position in which one escape wheel tooth drops off one pallet stone and another tooth locks on the other pallet stone. To be slightly less than the lock, it must not allow the escape wheel to unlock from the pallet stone when the fork is moved back and forth. Also, it must be great enough to allow the jewel pin to pass the horns of the fork (figure 96) with perfect freedom after the balance has been released. The

jewel pin shake must then be tried to make sure that it is equal on both sides of the line of centers. (The desirable jewel pin shake for pocket watches is about 0.02 mm.)

As regards maximum and minimum jewel pin shake, with a perfect lock, the jewel pin shake is great enough when the pin

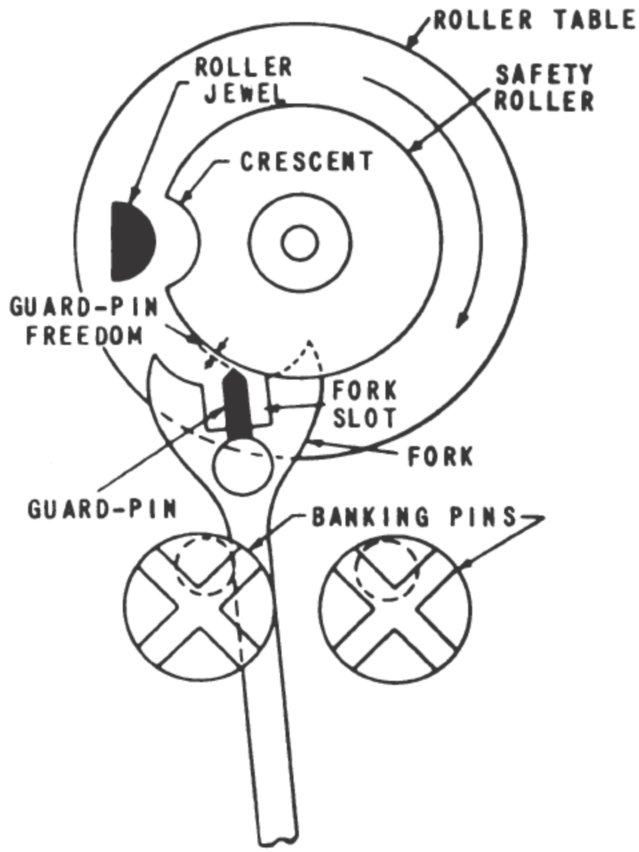



Figure 97. — Correct guard pin shake.

will pass out of the fork slot at the time of the DROP, and it is light enough when, with a perfect lock, it will keep the pallet stone securely locked. These conditions are also referred to as LONG AND SHORT FORK. If the jewel pin will not pass out of the fork slot when the fork is banked to the drop, it is called LONG FORK. If the jewel pin shake is so great that it allows the pallet stone to unlock when the fork is banked to the drop, it is called SHORT FORK.

*Guard pin shake.* — After the lock, drop, jewel pin shake, and draw have been inspected and the jewel pin shake has been found to be equal on both sides, the escapement can then be

tried for guard pin shake. When the fork is banked to the drop the guard pin shake should be perfectly adjusted. That means it must be free enough to allow the balance to move freely when the watch is in either a horizontal or vertical position.

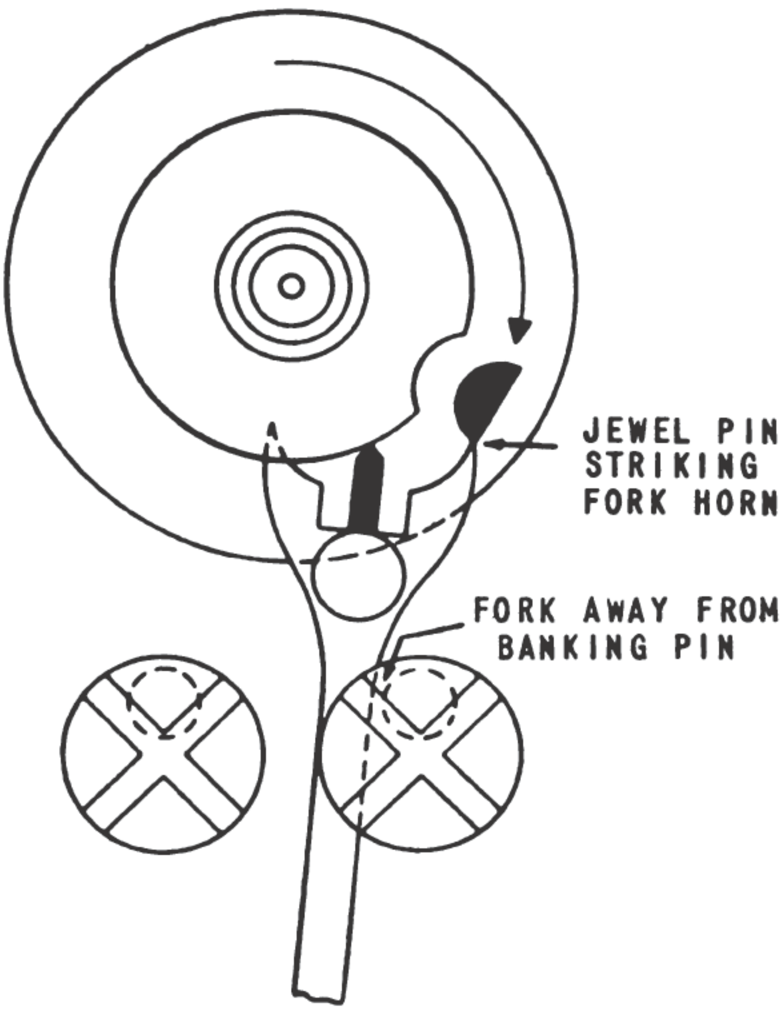



Figure 98.—Jewel pin striking fork horn because of excessive guard pin shake.

It also must be close enough to keep the escape teeth securely locked on both pallet stones. If the guard pin shake conforms to these two tests at drop, the guard pin shake will be correct after opening the banking pins later to give the escapement slide. (See figure 97.) The guard pin shake should be slightly less than the lock and should be tried at any position after the jewel pin has passed out of the fork slot and is completely detached from it. To be less than the lock, it must not allow the escape wheel tooth to unlock when moving the fork back

and forth. When the guard pin shake is excessive, we have the condition shown in figure 98.

*Slide.* — When the escapement is banked to the drop all the conditions of lock, drop, jewel pin shake, and guard pin shake conform to the theoretical design of the escapement. But such an escapement is too closely adjusted to be practical, because an escapement requires some freedom to be able to function properly. Turning each banking pin a small amount away from the line of centers will give this freedom. Opening the banking pins this way allows the pallet stones to slide on the escape wheel teeth. The slide should be one fourth the amount of the lock.

The slide is, therefore, the distance that the pallet stone slides on the escape wheel after the balance is moved from the position in which the jewel pin shake is tried. Its direction is away from the line of centers.

*Width of jewel pin.* — The width of the jewel pin should be tried with the jewel pin located in a direct line with the escape wheel, pallet, and balance centers. It should be 0.002 cm. or 0.003 cm. smaller than the fork slot.

*Draw.* — As stated above, the draw on the pallet stones and escape wheel teeth is for the purpose of holding the fork securely against the banking pin, thereby preventing the guard pin from rubbing against the roller during the detachment of the jewel pin from the fork slot. Obviously, the fork must be held securely against the banking pin during the locking period to allow the balance and roller to turn unmolested while the fork is detached from the jewel pin.

## CORRECTING ESCAPEMENT ERRORS

*Strong and light lock.* — A strong lock caused by both pallet stones being moved out an equal distance will increase the jewel pin shake and the guard pin shake. It will also make the drops unequal. A slight movement of the pallet stones in and out will not affect the drops enough to make the escape wheel teeth catch on the pallet stone: neither will that condition appreciably increase or decrease the draw. Correcting the error

of strong lock by pushing both stones in will also correct excessive jewel pin and guard pin shake. If both the stones are not pushed in, the banking pins will have to be opened farther to allow the impulse to let off. A strong jewel pin shake will result.

A strong lock caused by the *L* stone being moved out, as illustrated in figure 99, will make the jewel pin and guard pin

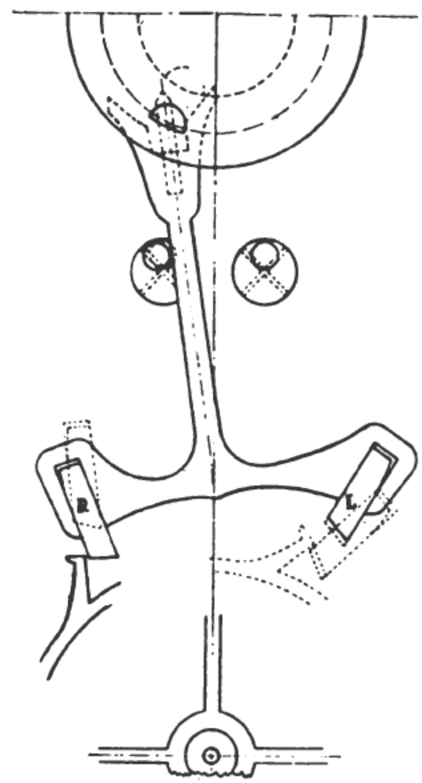



**Figure 99. — Advanced L stone affecting jewel pin and guard pin shake.**

shake unequal, and strong on the *R* stone side. This also causes the drops to be unequal, or CLOSE INSIDE. Correcting the error of strong lock by moving the *L* stone in will at the same time correct the jewel pin and guard pin shake, and equalize the drops.

A strong lock caused by the *R* stone being moved out, as shown in figure 100, will make the jewel pin and guard pin shake unequal, and strong on the *L* stone side. This also causes the drops to be unequal, or CLOSE OUTSIDE. Correcting the error of strong lock by moving the *R* stone in will at the same time correct the jewel pin and guard pin shake, and equalize the drops.

A light lock caused by both stones being moved IN an equal distance will decrease the jewel pin and guard pin shake. Correcting the error of light lock by pushing out both stones will at the same time correct the jewel pin and guard pin shake. Correcting this lock will necessitate closing the banking pins slightly, enough to allow the impulse to let off. A light jewel pin shake or a LONG FORK will result.

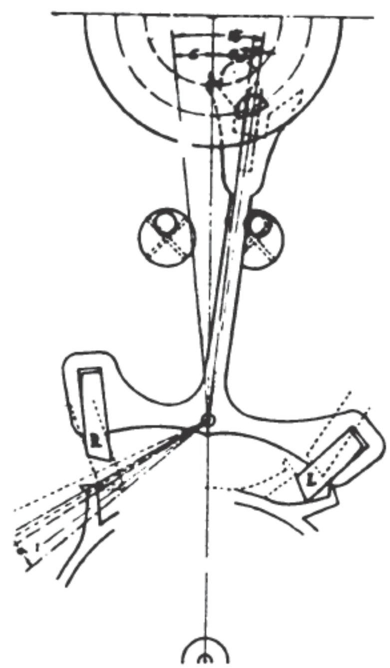



**Figure 100.—Advanced R stone affecting jewel pin and guard pin shake.**

A light lock caused by the *L* stone being moved in will make the jewel pin and guard pin shake light on the *R* side. This also causes unequal drops, of CLOSE OUTSIDE.

A light lock caused by the *R* stone being pushed in will cause the jewel pin and guard pin shake to be unequal, and light on the *L* side. It also causes the drops to be unequal, or CLOSE INSIDE. Correcting the error of light lock by moving the *R* stone out will increase the lock and correct the jewel pin and guard pin shake. This will also equalize the drops.

When it becomes necessary to move pallet stones, this may be accomplished through the use of a pallet warmer, an alcohol lamp, tweezers, and shellac. The fork and pallet are removed

and placed on the pallet warmer with the flat top surface down. (See figure 101.) One edge of the warmer is heated with the alcohol lamp. A shred of shellac is placed around each pallet

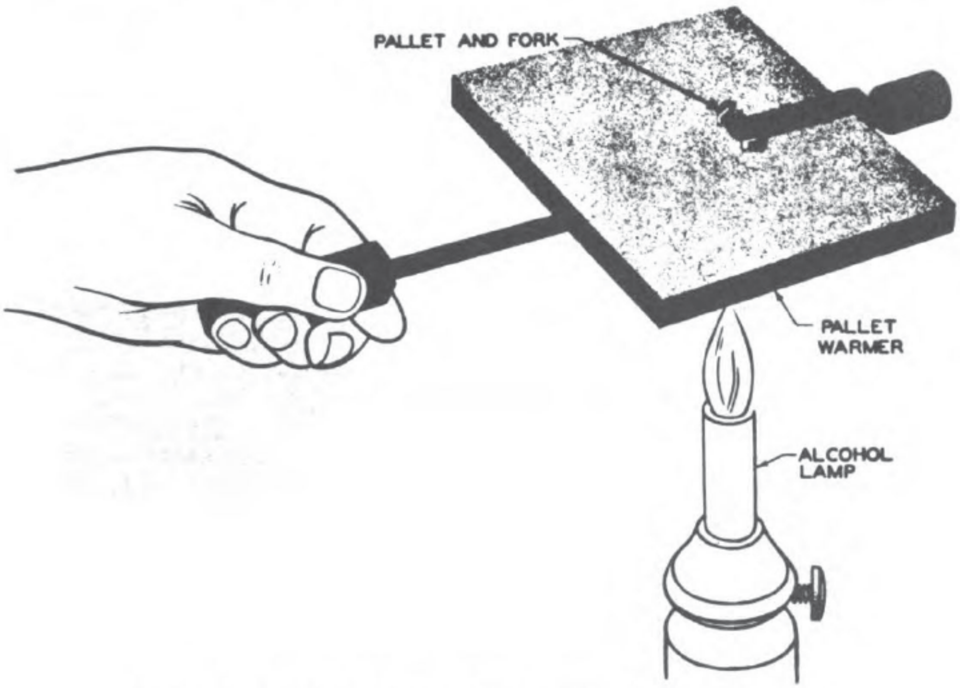



**Figure 101. — Pallet warmer used in adjusting pallet stones.**

stone, and as the pallet warms up, the old shellac softens, allowing the stones to be moved with the tweezers. The tweezers should never be allowed to touch the jewels during heating, as this might cause the jewels to crack. Great accuracy is required in making the pallet stone adjustments; the use of a double-eye loupe is recommended here. After the stones are positioned, the cooling shellac hardens and holds the stones firmly in place.

*Jewel pin shake.* — The jewel pin can be moved towards or away from the fork slot. The guard pin can be moved towards or away from the roller. If it is found that the jewel pin will not pass out of the fork slot after it is reset, it may be moved in the direction of the balance staff. Likewise, if there is too much jewel pin shake, the jewel pin may be moved a little way towards the fork slot. (See figure 96.)

When jewel pins must be reset, a pin is selected to fit the slot and then cleaned thoroughly with alcohol to remove grease, dirt,

or any old shellac. The roller table is removed from the balance and placed in the roller table warmer (see figure 102), and a small piece of shellac is placed on the roller table over the jewel

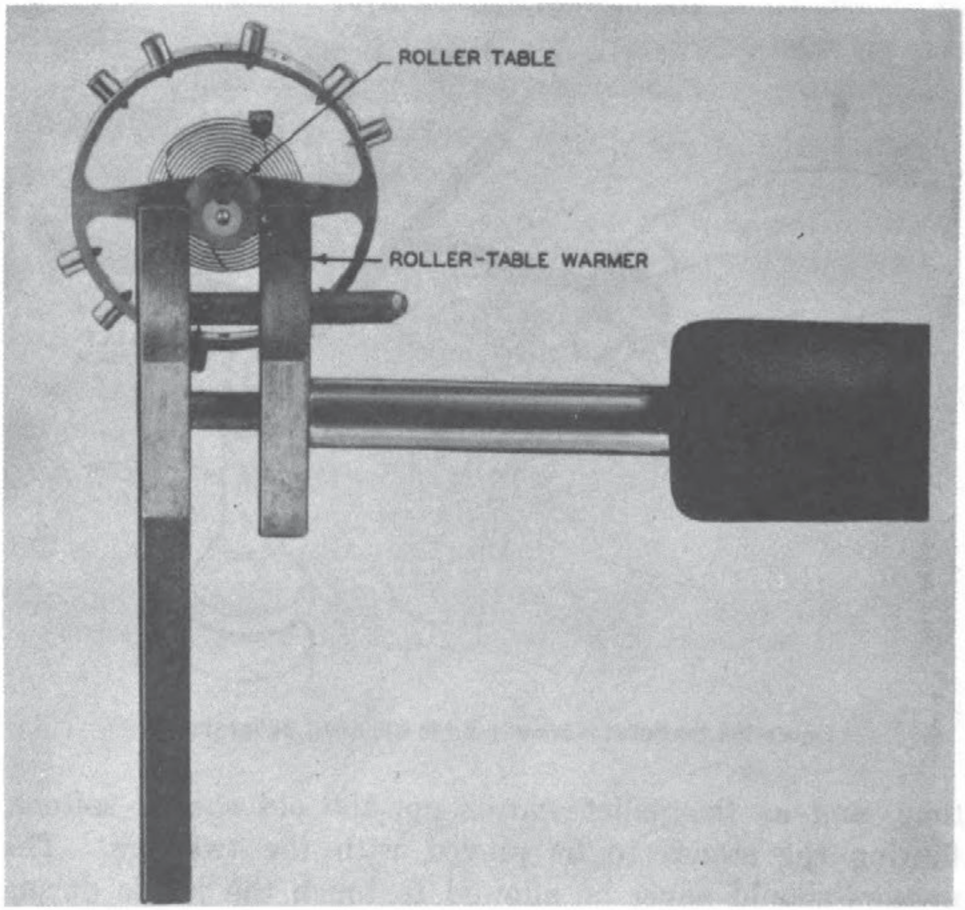



**Figure 102.— Roller table warmer used in setting jewel pins.**

pin hole. The end of the roller table warmer is heated until the shellac melts. The new jewel pin is now positioned in its hole. The excess shellac is removed and the jewel pin carefully adjusted to a vertical position.

A jewel pin should never be set sideways to correct an unequal jewel pin shake. To correct unequal shake which is strong on the *R* stone side and has a strong lock, push in the *L* stone and then BANK TO THE DROP.

To correct an unequal jewel pin shake which is strong on the *R* stone side and has a light lock, pull out the *R* stone and BANK TO THE DROP.

To correct an unequal jewel pin shake which is strong on the *R* stone side and has a strong lock, push in the *R* stone and BANK TO THE DROP.

To correct an unequal jewel pin shake which is strong on the *L* stone side and has a light lock, pull out the *L* stone and BANK TO THE DROP.

With a perfect lock and drop and an unequal jewel pin shake, bend the fork and the BANK TO THE DROP. The fork should be soft enough to bend without breaking; if the fork is too brittle, the safest course is to move one stone out and the other in.

If the jewel pin shake is stronger on the *R* stone side, move the *R* stone out and the *L* stone in.

If the jewel pin shake is stronger on the *L* side, move the *L* stone out and the *R* stone in.

*Unequal drops.* — An unequal drop, CLOSE OUTSIDE, is caused by moving the *R* stone out and the *L* stone in.

An unequal drop, *close inside,* is caused by moving the *L* stone out and the *R* stone in.

1. *Close outside.* — To correct CLOSE OUTSIDE with a PERFECT LOCK, the *L* stone must be moved out and the *R* stone moved in.

To correct CLOSE OUTSIDE with a STRONG LOCK, the *L* stone must be moved out and the *R* stone moved in.

To correct CLOSE OUTSIDE with a LIGHT LOCK, the *L* stone must be moved out.

2. *Close inside.* — To correct CLOSE INSIDE with a PERFECT LOCK, the *R* stone must be moved out and the *L* stone moved in.

To correct CLOSE INSIDE with a STRONG LOCK, the *L* stone must be moved in.

To correct CLOSE INSIDE with a LIGHT LOCK, the *R* stone must be moved in.

3. *Imperfect drops.* — To correct imperfect drops with a LIGHT LOCK, the stone that has the LEAST drop must be pulled out.

To correct imperfect drop with a STRONG LOCK, the stone that has the MOST drop must be pulled out.

*Unequal locks.* — The effect of moving the *R* stone out is to increase the lock on both sides, but this increases the lock more on the *L* than on the *R* stone. Also, moving out the *L* stone

increases the lock more on the *R* than on the *L* stone. This adjustment is so slight, though, that it cannot be depended upon to correct an unequal lock where the difference is sizeable.

Unequal lock is corrected by either changing the pallet stones or by moving them in and out. The thicker the stone, the lighter the lock will be. The thinner the stone, the stronger the lock will be. So, in order to equalize an unequal lock, a thicker or thinner pallet stone, as the conditions may require, is installed.

If the lock on the *R* stone is stronger than the lock on the *L* stone, either a thinner *L* stone or a thicker *R* stone must be installed.

*Impulse.* — The effect on the impulse of moving the pallet stones is as follows:

Moving the *L* stone OUT and the *R* stone IN decreases the impulse on both stones.

Moving the *R* stone OUT and the *L* stone IN increases the impulse on both stones.

Moving the *R* stone OUT increases the impulse on both stones.

Moving the *R* stone IN decreases the impulse on both stones.

Moving the *L* stone OUT decreases the impulse on both stones.

Moving the *L* stone IN increases the impulse on both stones.

*Draw.* — The draw is affected very appreciably when the pallet stones are moved in and out.

Moving the *R* stone IN and the *L* stone OUT decreases the draw on both stones.

Moving the *R* stone OUT and the *L* stone IN increases the draw on both stones.

These last two moves take us back to the discussion on unequal jewel pin shake where these changes of pallet stone position were considered. If all the conditions mentioned above are studied carefully with frequent reference to the escapement drawing (figure 95), the theory of the escapement will become clear and extremely interesting, and by cross-checking the different conditions and the moves recommended for each condition, a great deal of knowledge and personal satisfaction will be gained. Figure 103 shows all the parts of the escapement in their operating positions.

*Slide.* — The slide can be tested by holding the watch in the left hand with the first finger touching the edge of the balance wheel and steadied against the pillar plate. With the jewel pin in the fork slot, the balance is moved around very slowly until

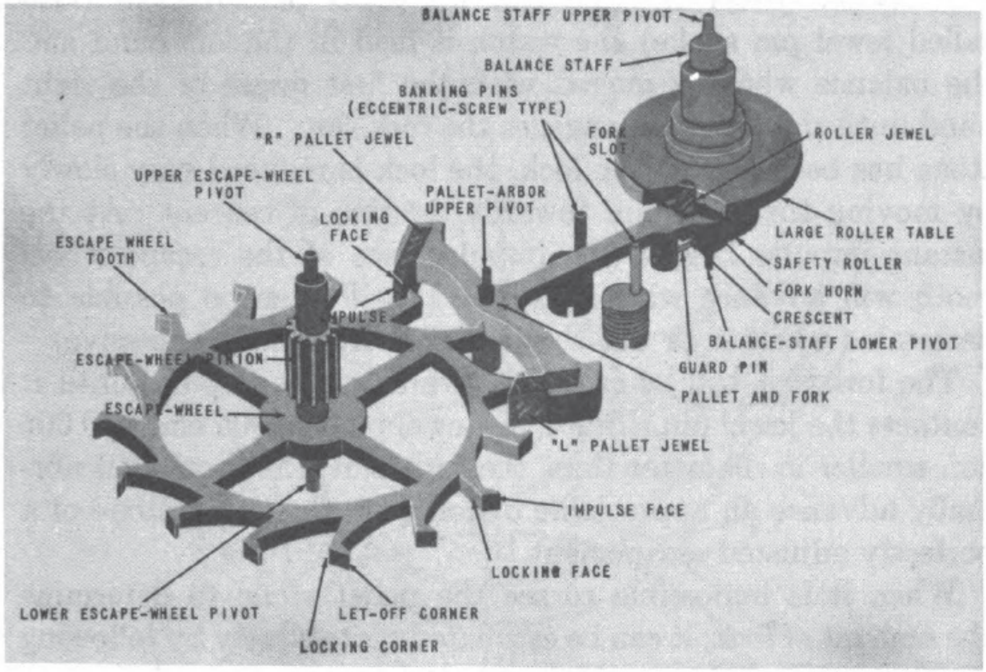



Figure 103. — The escapement.

the impulse lets off and escape wheel tooth comes to lock. The amount of lock can then be observed to see that it is about one fourth of the pallet stone face. The balance is then given a quick turn so as to carry the jewel pin well out of the fork slot. Through the peek holes in the pillar plate, and with the use of a double eye glass, the slide can be observed without great difficulty.

*Safety action.* — After the escapement has been matched, it should be tested to see if the safety action works properly. The balance is again moved slowly with the first finger so that the jewel pin passes in and out of the fork slot, and the train is reversed with a fork tool at the third or fourth wheel. This will make the escape wheel turn backwards, throwing the guard pin forcibly against the safety roller. If correctly adjusted, the jewel pin will readily re-enter the fork slot. The balance wheel

is then turned slowly until the jewel pin touches the other side of the fork horn; the train is reversed and the balance released again. If the jewel pin is carried safely back into the fork slot from this side, too, the safety action can be accepted as satisfactory.

*Jewel pin freedom.* — To test for jewel pin freedom (also called jewel pin shake) the watch is held in the left hand and the balance wheel is moved with the first finger of the right hand until the jewel pin engages the fork slot. When the pallet stone has been brought to lock, the lock is reduced very slowly by moving the jewel pin towards the line of centers. At the instant impulse begins, the impulse face of the escape wheel tooth will advance with a jump. It will then be possible to determine whether or not the jewel pin freedom is excessive.

The fork slot will be carried forward by the impulse until it contacts the jewel pin. Since the jewel pin is 0.005 cm. or 0.006 cm. smaller in diameter than the fork slot, the tooth will normally advance an appreciable distance on the pallet stone of a perfectly adjusted escapement.

When it is impossible to see the pallet stone to determine the amount of lock, it can be estimated quite closely by following the first part of this method and then watching carefully how far the fork moves backwards before the escape wheel unlocks. By practicing with watches where the lock can be seen, you can learn to check the jewel pin freedom in models where the lock cannot be seen.

Now, as a final test of the safety action, the third or fourth wheel is reversed again with the fork tool, so that the guard pin will be thrown against the edge of the roller, and the balance is rotated a full turn in each direction, taking the jewel pin in and out of the fork slot. If the fork and pin stay in their proper positions during the test, it can be assumed that the safety action is satisfactory. If the pin will not enter the fork slot, it indicates that (1) the guard pin shake is not perfectly adjusted, (2) the jewel pin shake is too light, (3), the corners of the jewel pin are too sharp, or (4) the faces of the fork horns are rough. In any case, the necessary adjustment should be made and the final safety action test repeated.

The effect of moving both pallet stones out is shown in figure 104. The pallet is no longer CIRCULAR, so the stones are not properly adjusted. It can be noted from this illustration that moving the *R* stone out increases the circle's radius, while moving the *L* stone out decreases its radius. This condition causes unequal drops.

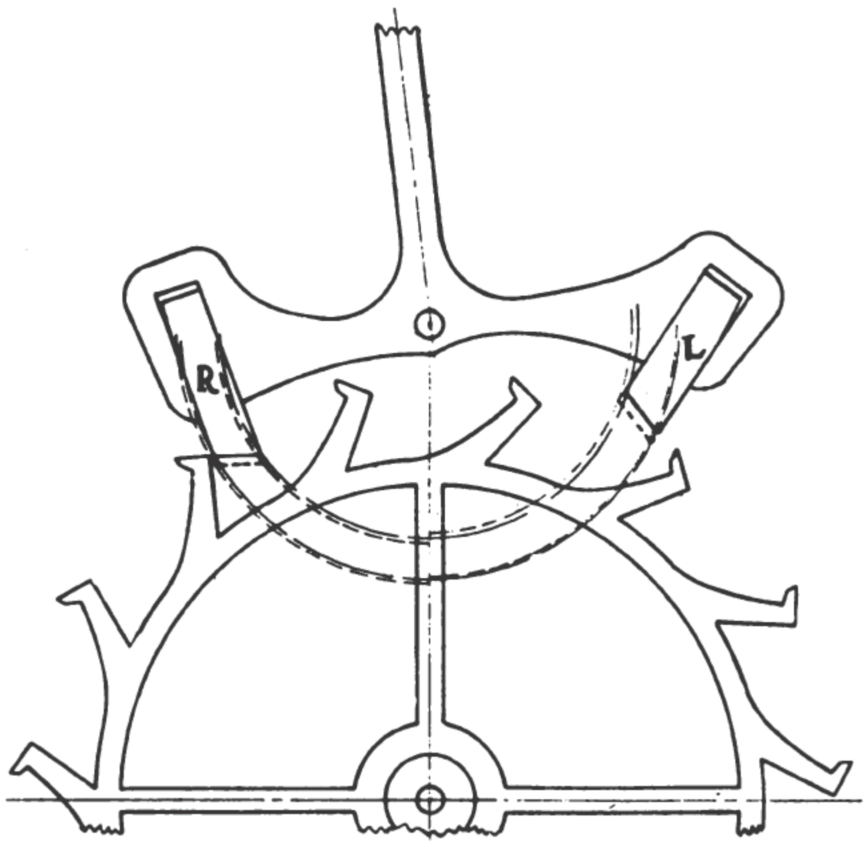



Figure 104. — Both stones moved out; pallet no longer circular.

In figure 105 (left) the correct lock and jewel pin shake, as well as their relation to each other, is shown. If the fork were too long and the jewel pin radius too long, the condition shown in figure 105 (center) would result; i.e., the jewel pin would not pass out of the fork slot and there would be no jewel pin shake at all. If the fork or jewel pin radius were too short, there would be too much jewel pin shake and the escape wheel tooth would unlock, as shown in figure 105 (right).

The final check on the escapement is to make sure that it looks correct from the side. The guard pin must pass through

the CENTER of the safety roller (not above or below it) and must not strike the lower end of the jewel pin. The fork should not rub on the large roller, and both pallet stones should be in the

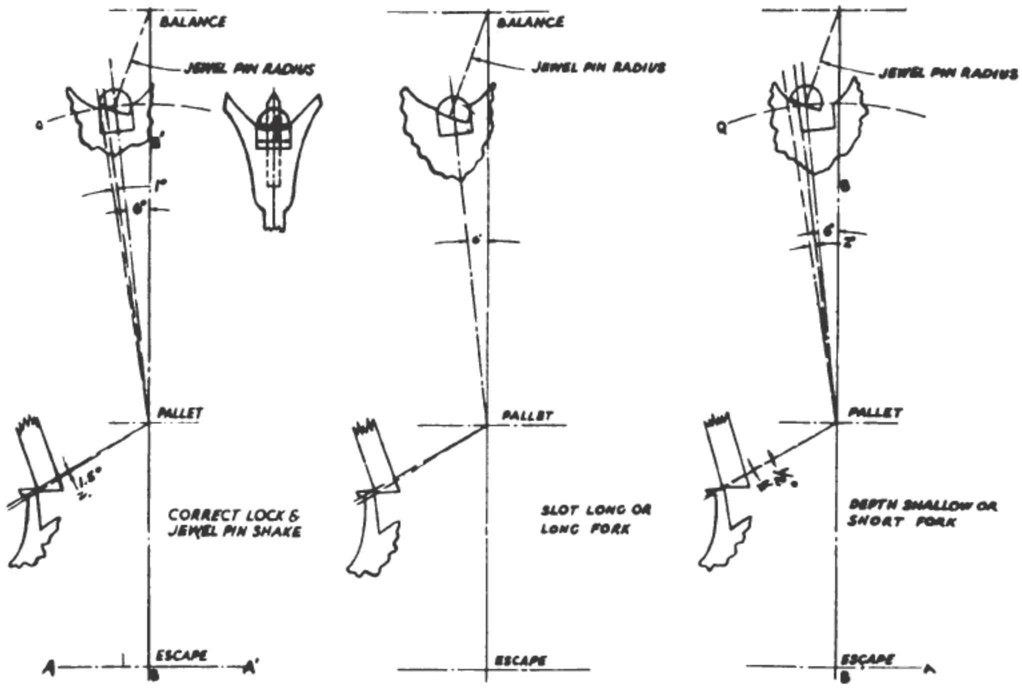



Figure 105. — Correct and incorrect lock and jewel pin shake.

plane of the escape wheel. If the escape wheel has too much endshake this last condition will not always exist.

## PUTTING A WATCH "IN BEAT"

A watch is IN BEAT when the same amount of power is required to start the balance in one direction as in the other. This means there is no tension exerted by the hairspring to either side when the escapement is at dead center. This condition exists when, with the hairspring unstressed, the jewel pin lies on the line of centers of the balance pallet arbor, and escape wheel. (See figure 106.) If the hairspring when unstressed holds the jewel AT AN ANGLE with the center line, the watch is said to be OUT OF BEAT.

To test whether or not the watch is in beat, it is placed in the dial-down position with its mainspring about half wound, and a beat tool or other pointed object is held at the side of a balance screwhead to try to stop the balance by causing an escape

wheel tooth to stay locked on either the *R* or the *L* stone (see figure 107.) If the motion of the balance CANNOT be stopped that way, the watch is in beat. If the balance CAN be stopped that way, the side of the center line on which the jewel pin stopped is determined. This is done by pushing a balance

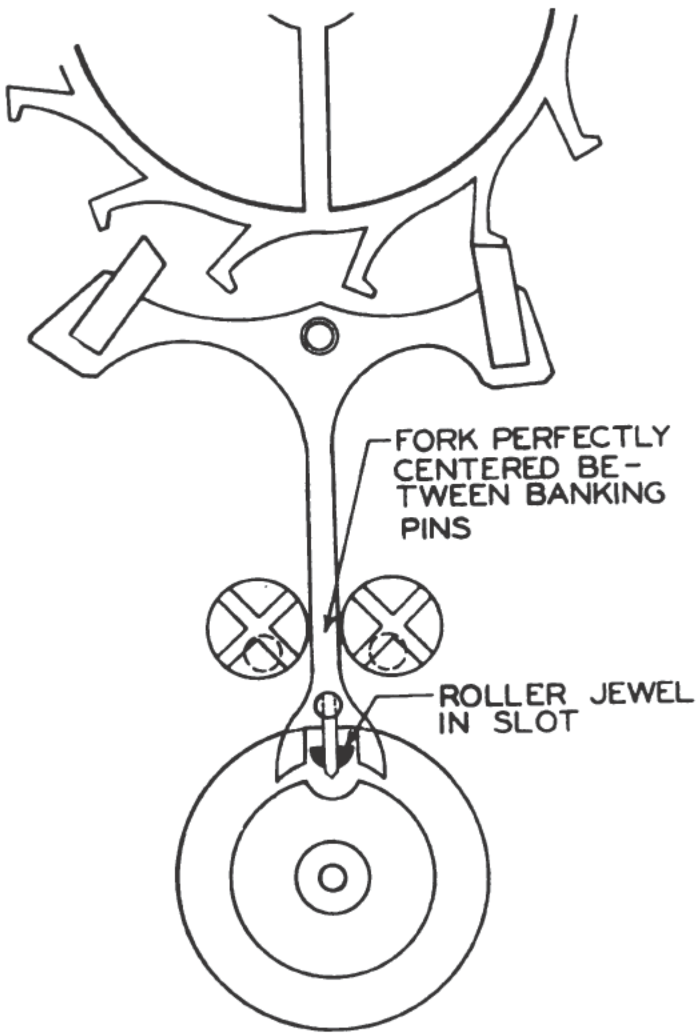



Figure 106.— Watch "in beat."

screw lightly in one direction with the beat tool; if the watch starts, that direction can be considered to be the right direction for starting. The position of the jewel pin with reference to the line of centers can then be located. When the balance wheel is stopped, the pallet remains locked on the *L* stone. The jewel pin comes to rest at the left of the centerline. Pushing

the balance in the direction of the arrow would make it continue to turn in that direction, until it reached the end of a vibration, showing that the jewel pin stopped at the left of the centerline.

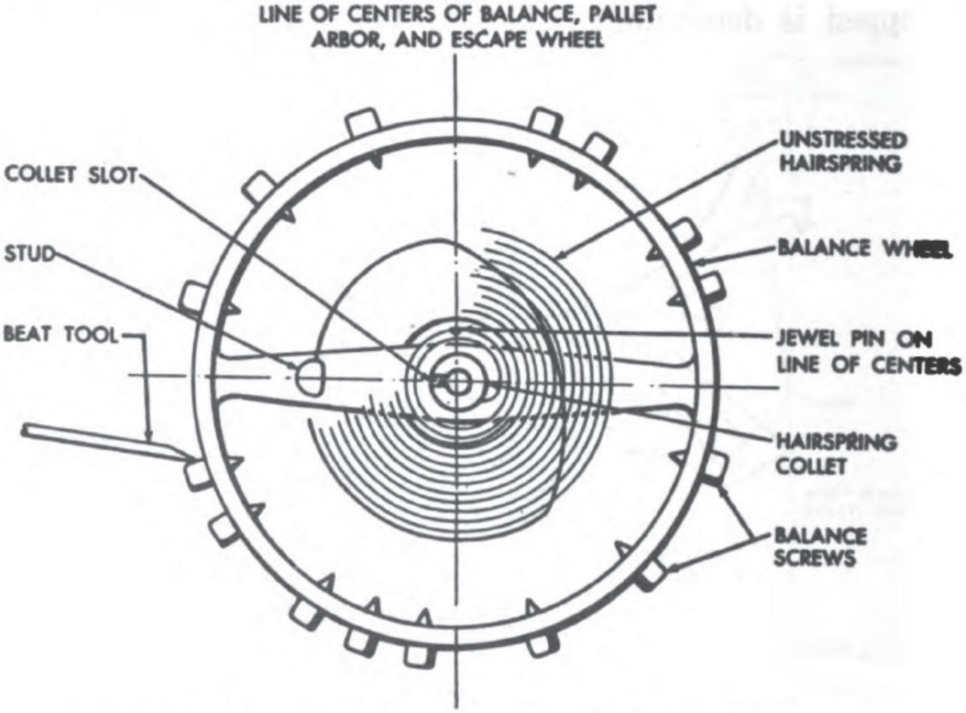



Figure 107. — Testing with beat tool to determine if watch is in beat.

To correct the error and bring the watch in beat, either (*a*) the balance wheel can be turned manually in the same direction as the starting push while the collet is held rigidly in place with the beat tool, or (*b*) the collet can be moved in the opposite direction while the balance wheel is held firmly in place. Only experience can show you exactly how far to move the collet in order to put the escapement in beat this way when such action is found to be necessary.

## Adjusting a Watch to 5 Positions

The procedure followed when adjusting a good watch, such as a Navy comparing watch, to five positions, assuming that it has been correctly repaired and has a good motion, is as follows:

1. *Horizontal adjustment.* — Position the regulator lever at 0 (halfway between *S* and *F*.), and establish the correct weight

of the balance wheel in the *DU* (dial up) and *DD* (dial down) positions. This is done by first determining the watch's timing through the use of the timing machine (see below), and if necessary manipulating the mean-time screws on the rim of the balance until a correct rate (neither gaining or losing) is shown in these positions. This gives adjustment for these two horizontal positions.

2. *Vertical adjustment.*—Poise the balance wheel. (See chapter 3.) Compensate for the heavy point, if there is one, either by adding timing washers in opposite pairs to the balance or moving the mean-time screws inward or outward as required. Test the rate in the timing machine for *PU*, *PR*, and *PL* (12 up, 9 up and 3 up) positions. If the balance wheel weight and poise are correct, the watch will show a correct rate in all of these positions. If a gaining or losing rate is shown in one or more of these positions, repeat the poising operation and check the timing again in the several positions. This gives the adjustment for three vertical positions.

When the watch has been adjusted so that it shows a correct rate in each of these five positions, it will keep almost perfect time in all of those positions.

## REGULATION

After careful position adjusting has been done, the watch may keep perfect time in the shop and yet be erratic when put into service. This is because of the widely varying conditions under which some watches are expected to perform. It may happen that the watch will be wound at irregular intervals. Some people wear watches for only a brief period at a time, allowing them to lie in a horizontal position when not in use. Some occupations put unusual stress on watches. This makes it advisable sometimes to further adjust the timepiece to the routine of the person who wears it.

A watch whose rate has been adjusted to isochronism, temperature, and position may still run several minutes a day fast or slow, and require regulation. The usual procedure for altering the rate slightly is to move the regulator lever to *F* or *S*, as required. The movement towards *F* (fast) decreases the

effective length of the hairspring between the regulator pins and speeds up the watch. Moving the regulator lever toward *S* (slow) has the opposite effect.

If the watch fails to keep correct time after maximum movement of the lever, some adjustment must be made on the balance wheel. A pair of mean-time screws must be screwed inward or outward. This adjustment slightly changes the position of the center of gravity. While the screw adjustments are being made, the regulator index should be at 0 in the center of its movement.

If the tightening or loosening of these screws still fails to regulate the timing of the watch, adding timing washers in opposite pairs or moving the mean-time screws in pairs will accomplish this purpose. If it is a high-grade watch, reference to the maker's regulation charts will tell you quickly the effect of ¼, ½, or 1 turn of the mean-time screws on the timing.

Very often, the cause of an erratic rate is a weakened mainspring. For this reason the mainspring of every watch that is accepted for regulation should be removed from its barrel and checked for resiliency. If the spring when unstressed does not quickly return to its initial shape, or if its power appears to be weakened from service, a new mainspring should be installed as the first step in the regulation process.

To become a competent watch adjustor you must know the theory of poising thoroughly, also the effect of the regulator position and the effect of motion on the timing of a watch.

## THE TIMING MACHINE

The electric timing machine, sometimes called the watch rate recorder, is a comparison device which operates by comparing the rate of a watch to the rate of a correct source in the machine. This time standard is usually a vacuum tube or crystal-operated precision tuning fork having sufficient power to run a small synchronous motor and regulate its speed accurately. One type of watch timing machine is shown in figure 108.

When a watch is placed on the machine's microphone, the ticks are picked up and generate small electrical voltages. These impulses are amplified and applied to a trigger tube

connected to an electromagnetic stylus. Each time the watch ticks the trigger tube fires, and the stylus prints a dot. A metal drum is geared to the motor shaft and rotated at a speed accu-

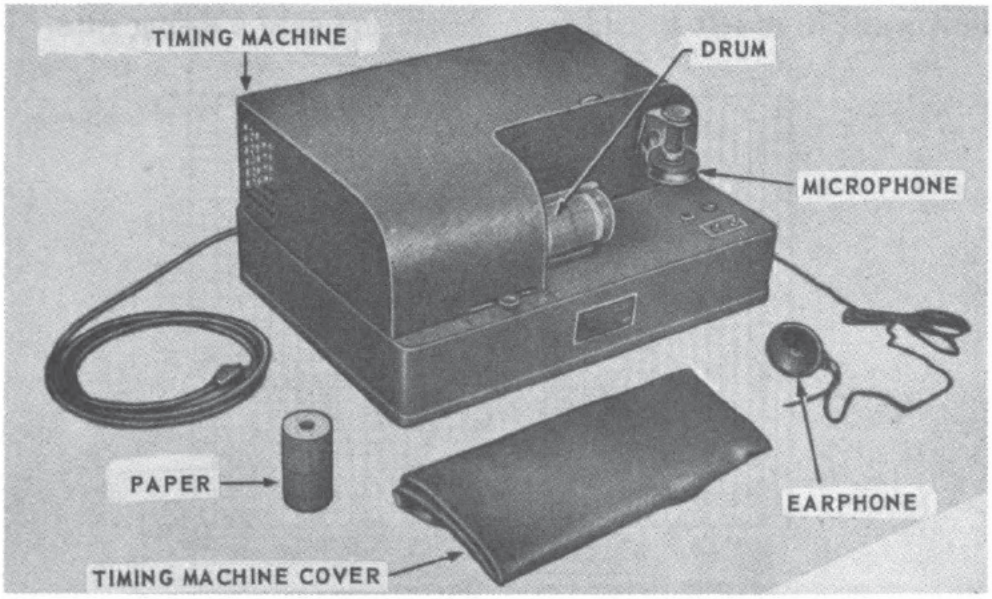



Figure 108.—Timing machine—conventional model.

rately controlled by the time source. A printed record is obtained of the difference in rate between the watch and the time standard.

The drum makes exactly five turns per second, or one turn in $\frac{1}{5}$ second. A standard 300 beat (per minute) watch ticks once every $\frac{1}{5}$ second; therefore it will tick once for every turn of the drum. If the drum were rotated with the stylus remaining stationary, all the dots would fall *one upon the other*. Actually, the stylus does not remain stationary, but is carried sideways along the drum by a screw which is also gear-driven by the motor, so with a correctly timed watch the dots will print in a straight line across the paper. A record printed by such a watch is shown at *A* in figure 109.

If the watch is fast, the time interval between ticks will be less than $\frac{1}{5}$ second, and the second dot will be printed *before* the drum has completed a full revolution. The third dot will be printed *before the third revolution* has been completed, and so on. The dots on the record will then form, not a straight

horizontal line, but one which slopes in the direction in which the paper is advancing. If the chart shows a record which slopes upward from left to right, as *B* in figure 109 does, this indicates a gaining rate. Conversely, a record which slopes downward from left to right, as *C*, will indicate a losing rate.

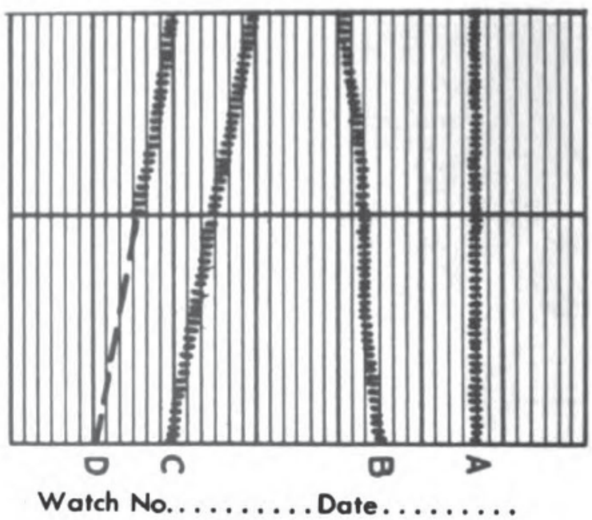
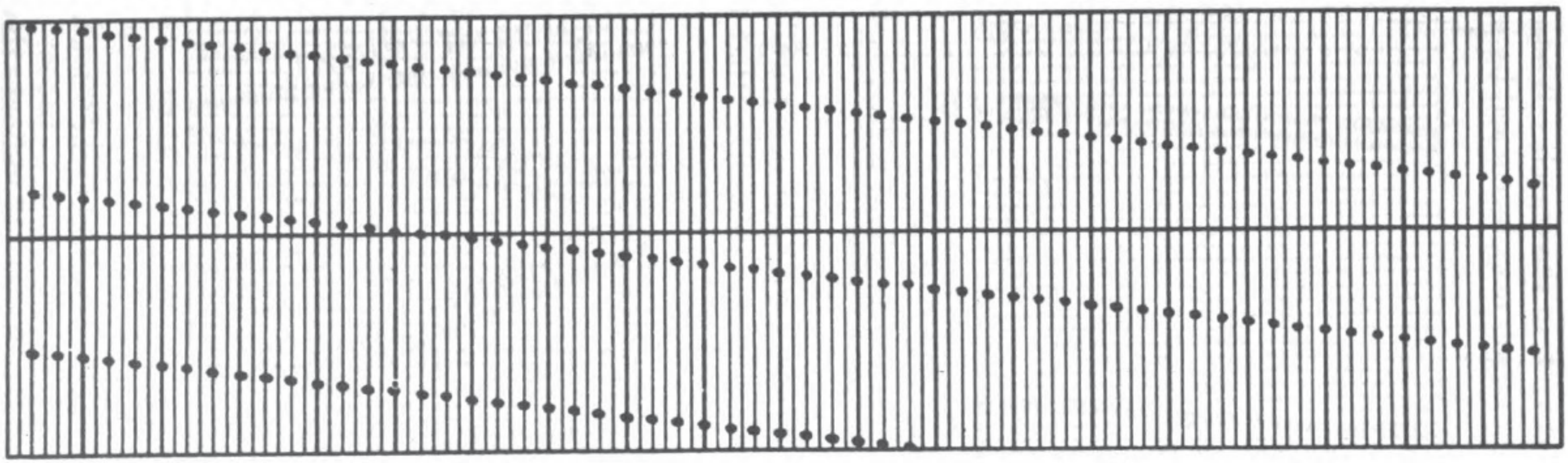



**Figure 109. — Typical chart record.**

The chart paper on the drum is 2 inches wide and has been calibrated to record the 24-hour performance of the watch on the width of the paper. The time required to make a 24-hour record is 30 seconds. The paper is ruled so that each division represents a time error of 5 seconds in 24 hours and for convenience in reading large errors, every sixth line is of double width and represents an error of 30 seconds in 24 hours. Record *C* (figure 109) represents a watch that is losing 30 seconds per day. When timing watches of average quality it is generally unnecessary to make the full 30-second reading in each position. The 15-second reading indicated in record *D* (figure 109) is usually sufficient to show the rate.

The records in figure 110 represent a watch which is gaining 1,560 seconds, or 26 minutes, every 24 hours.

A perfectly adjusted escapement will produce only one line on the chart. However, many watches produce records that consist of a double line of dots, as shown in figure 111. Record *A* in this figure shows the distance between these two lines as a direct measure of the time difference between the TICK and



Watch No. . . . . . . . . . Date . . . . . . . . .      Watch No. . . . . . . . . . Date . . . . . . . . .

Figure 110.—Chart record showing very fast rate (26 minutes per day).

TOCK and the TOCK and TICK in the watch. When the watch is in perfect beat, this separation may be caused by excessive slide

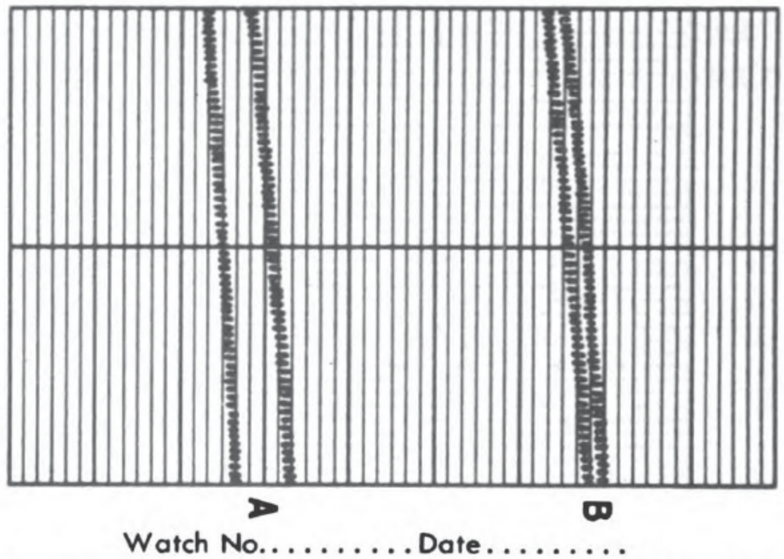



**Figure 111.—Chart record for two watches in same position, showing two lines of dots instead of one.**

in the escapement. If the two lines are parallel and close together, as in record *B*, it is safe to assume that the watch is in good condition.

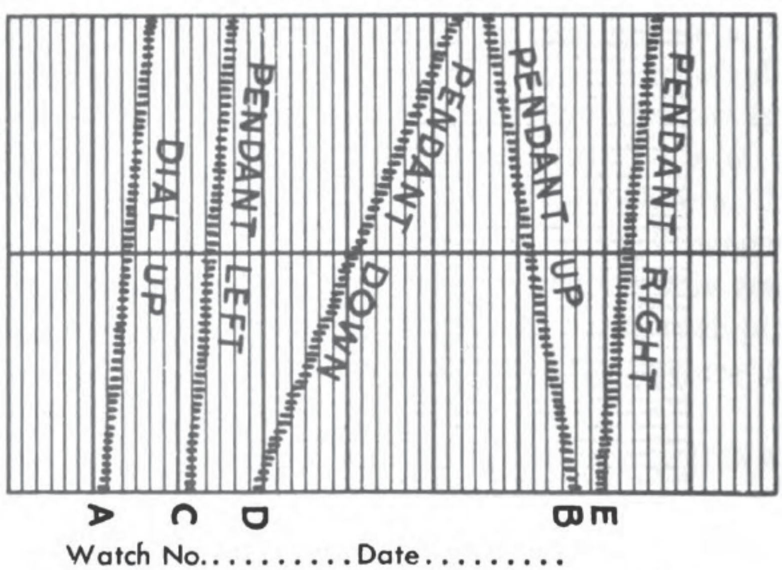
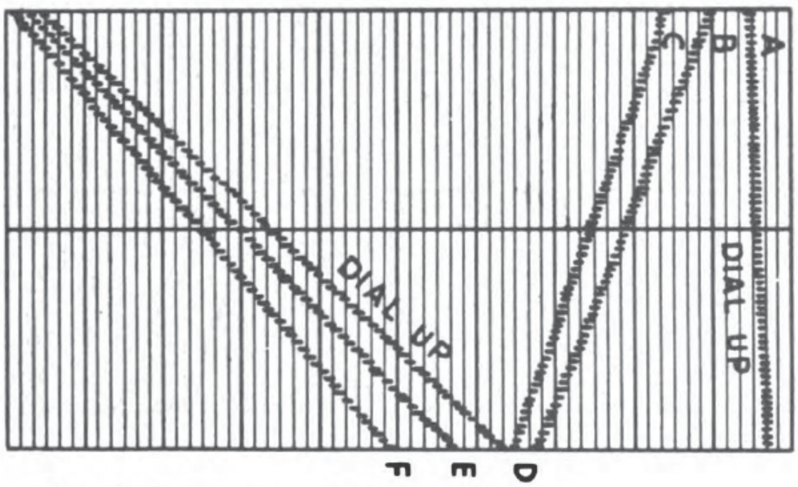



**Figure 112.—Record showing out-of-poise balance.**

The records *A*, *C*, and *E* in figure 112 indicate that this watch is in acceptable condition. Records *B* and *D* show that the

watch is out of balance in these two positions. If the records *B* and *D* do not exceed the established limits for this grade of watch, the watch may be considered to be acceptable.

Records *A*, *B*, and *C* of figure 113 show three positions of a watch whose regulator pins may be set excessively far apart.




Watch No.........Date.........

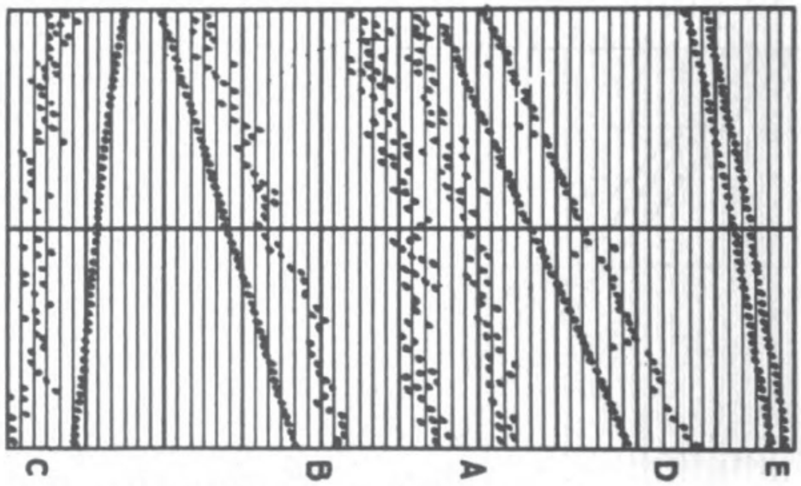
Figure 113.—Effect of opening regulator pins beyond 0.0006 inch.

The horizontal rate is about correct. But the *PU* (pendant up) and *PD* (pendant down or 6 up) rates are slow. Records *D*, *E*, and *F* show the rates for these three positions after the regulator pins have been moved closer together. The watch will then run faster in all positions, with the rates in the vertical position faster than those in the horizontal. Closing the pins brought the position error within the acceptable limits of 30 seconds. Further correction could be made by adding balance weights.

Much of the ordinary watch trouble is traceable to the hairspring, either to its position between the regulator pins or to defects in the escapement adjustment. Record *A* in figure 114 may indicate that the hairspring is bearing too strongly against one of the pins. Record *B* may show that one of the pins is bent. Records *B* and *C* may indicate improper locking of the escapement. Record *B* may show trouble in the receiving stone of the pallet; record *C* may indicate trouble in the discharge stone. Record *D* shows a good hairspring and good escapement adjustment, but may indicate that the watch's performance can

be improved by putting it in beat. That would bring the lines closer together, as in record *E*.

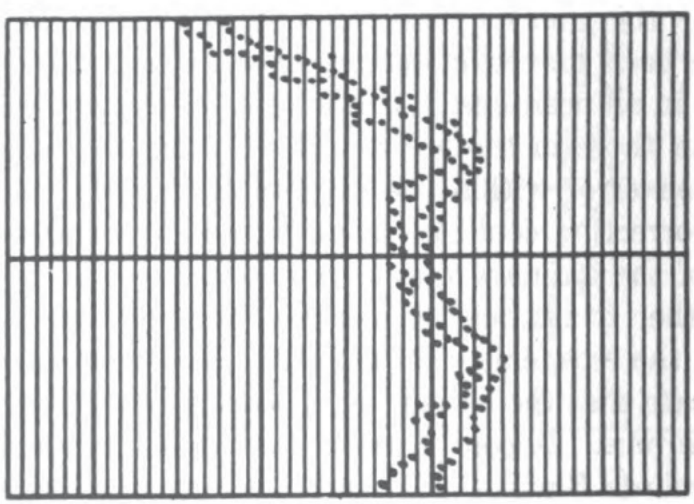
A common difficulty is illustrated in figure 115, which shows changes in power caused by friction that may be due to dirt, to




Watch No.......... Date.........

**Figure 114.—Chart record showing poor adjustment of hairspring and regulator pins.**

binding in the train, or occasionally to the mainspring binding in the barrel.



Watch No.......... Date.........

**Figure 115.—Chart record showing effect of excessive friction.**

It will be seen from these typical test results that the timing machine is an extremely useful device in providing a quick means of rating a watch. However, the student watch repairman should not try to use this machine for diagnosing watch troubles. The machine is so sensitive to vibration and to outside noises that it might indicate errors that do not actually exist. When any question is involved, a timing machine test should always be accompanied by an actual running test.

## SUMMARY

At this point, let us take a look at the ground that we have covered so far. You now have an understanding of the steps in the historical development of modern clocks and watches, knowledge that is important to every watch repairman. The four main parts of the watch, and the relation of each part to the complete watch mechanism, have been described for you.

The special tools used by watch repairmen have been described, and the techniques of their usage have been explained. We cannot overemphasize the importance of having a complete set of good tools, and of knowing when and how to use them. You have been told about the approved procedures for cleaning and oiling clocks and watches. The modern method of machine cleaning has been described in complete detail, since this is the cleaning method commonly used on Navy repair ships and at shore stations. The watch casualty analysis has been explained in detail, with methods of diagnosing and remedying the common watch troubles, and you have been given instructions on how to make certain watch parts in case no replacement parts are available. Such knowledge is valuable to the watch repairer, because it is through making the parts that he becomes thoroughly familiar with the intricate details of watch design and performance.

The functions of the detached lever escapement have been discussed, also the pallet stone adjustments and final escapement tests. Finally, the method of adjusting and regulating a watch with the use of the timing machine has been explained to you.

Conscientious study of the watch and clock repair section,

chapters 2 through 7, along with attendance and practical experience at the bench gained at the regular training meetings, will qualify you to become a well-trained watch and clock repairman. However, you will want to add to the knowledge that you have gained from this instruction by reading other books on watchmaking. While it has been said with a great deal of truth that "WATCH REPAIRING CANNOT BE LEARNED FROM BOOKS," it is also true that watch repairing cannot be learned WITHOUT BOOKS. A suggested reading list, prepared from the many books available on this subject, is included in appendix II of this manual. The understanding of watch repairing that you will gain in this work will give you a much more complete education than is received in most trades, for you will have learned something of the principles of mathematics, physics, and mechanical drawing and metallurgy, all of which enter directly into watchmaking; and you will use this knowledge daily in your work.

Outside reading will also keep you abreast of new developments in the watchmaking field. Such developments are constantly occurring. For instance, there is the new Dura-Power mainspring, which is rust-resistant, noncorrosive and nonmagnetic, and gives a smoother flow of power.

Your Navy will provide you with the proper equipment and good instruction. If you have confidence in your own ability and are willing to spend enough time doing practical watch repair work, then you will surely reach your goal as Instrumentman.

## QUIZ

1. What is the purpose of the escapement of a watch?
2. What is meant by BANKING TO THE DROP?
3. What is meant by LOCK?
4. What is meant by DROP?
5. What is meant by JEWEL PIN SHAKE?
6. What is meant by SLIDE?
7. What is meant by STRONG LOCK?
8. How does strong lock affect the jewel pin shake, the guard pin shake, and the drops?

9. What is meant by LIGHT LOCK?
10. How does light lock affect the jewel pin shake and the guard pin shake?
11. Which repair tools are needed to move pallet stones?
12. What is the correct position of the jewel pin in the pallet?
13. What is meant by CLOSE OUTSIDE?
14. How is CLOSE OUTSIDE corrected to give a PERFECT LOCK?
15. What is meant by CLOSE INSIDE?
16. How is CLOSE INSIDE corrected to give a PERFECT LOCK?
17. How is the draw affected when the *R* pallet stone is moved in and the *L* pallet stone moved out?
18. How is the draw affected when the *R* pallet stone is moved out and the *L* pallet stone is moved in?
19. After the escapement has been matched, which three final tests should always be made to check the escapement adjustment?
20. How is the slide adjustment made, and why?
21. How is the safety action check made?
22. How is the jewel pin freedom check made?
23. What steps would you follow in adjusting a watch to five positions?
24. If the chart from a timing machine shows a record which slopes downward from the left and drops six divisions on a 30-second test, is the watch gaining or losing, and how much?

# CHAPTER 8

# TYPEWRITER REPAIR TOOLS

## AN INDISPENSABLE MACHINE

Typewriters are an indispensable part of today's Navy. Invented in 1874, the typewriter has developed into the world's best known office machine, and it is found now on practically every American naval vessel.

The typewriter is unquestionably an ingenious machine. (Incidentally, if you don't fully understand what a MACHINE is, read *Basic Machines*, NavPers 10624, which explains the theory of levers, blocks and tackle, inclined planes, screws, and gear wheels. Most of these machine elements are used in a typewriter.) The typewriter carries type letters in the ends of steel bars. The typebars are pivoted, and when the keys attached to the bars are depressed, the bars rise sharply to a common center on a rubber cylinder carrying the paper. An inked ribbon passing between the cylinder and the typebar head provides an inked impression of the typehead on the paper. Each typebar has two characters, and through the use of the shift key either character may be printed. An average operator can write 60 words a minute on a typewriter, or about three times as many words as he can write in longhand.

While the typewriter is truly a wonderful mechanism, you

can't perform miracles with it. A Yeoman once reported that he had trouble trying to write the words, HAPPY BIRTHDAY on a cake. HOW WAS THAT? asked a shipmate. "I couldn't get the cake into the typewriter," the yeoman replied.

Naturally, typewriters should be used intelligently; if used that way, they will give many years of service. Typewriter makers claim that the modern typewriter never really WEARS OUT, if it is not dropped or otherwise abused. The fact is, with ordinary, careful use and with frequent cleaning and adjusting, typewriters will usually give more than a decade of useful, satisfactory service.

Typewriters in active service should be brushed out well by the operator at the end of each day. For best results, they should be thoroughly cleaned and adjusted by an Instrumentman after each 6-months' period of service. You will learn the details of that work from the next four chapters. Practice each step of typewriter disassembly, reassembly, and adjustment as you go along, trying out each procedure several times until you are sure that you know it thoroughly.

## TYPEWRITER SERVICE TOOLS

The screw driver is one of the most important tools used in typewriter repair. Its main job is to loosen and tighten screws. When repairing typewriters, you may often be tempted to use a screw driver for other purposes; but you'll do much better work if you resist this temptation and always use each tool for its own particular purpose.

Three or four different sizes of standard screw drivers are used in repairing typewriters. The commonly used lengths are the 10½-inch, 8½-inch, 6½-inch, and 4½-inch; the blades are of several thicknesses to fit the slots in the various screwheads. Most typewriter repairmen like to make their own screw drivers. You will probably want to make yours, too, eventually.

To make a screw driver for this kind of work, take a piece of ⅛-inch to ¼-inch drill rod of the desired length and grind the tip or end of the rod to the radius of the shop emery wheel, so that both sides are parallel. Be sure that the tip is straight and at right angles to the shank. The blade sides should taper

out to the shank body. A correctly ground tip is shown in figure 116. Flatten the other end of the drill rod, then fit it into a handle to complete the screw driver.

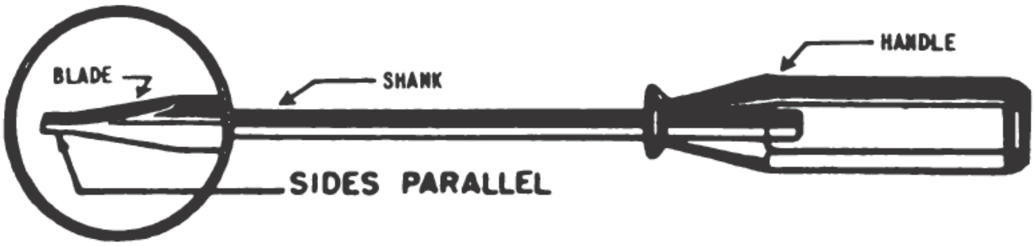



Figure 116. — Correctly ground screw driver tip.

The next step is to temper the tip of the blade to make it hard. Heat the tip to a cherry red, then quench it in water. The blackened tip is then polished to its original color with an emery cloth. Next, to toughen the new tip and remove some of the hardness so it will not be too brittle, return it to the flame for a few minutes, this time applying the heat to the tool at a point about 1½ inches from the tip of the shank. When a straw color reaches the tip, quench it in oil to cool it slowly. This will produce a hard, tough tip. Test its strength by tightening and loosening several screws. If the tip twists out of shape, the metal has been softened too much, so temper it again until it will stand a strong twisting force without changing its shape or breaking.

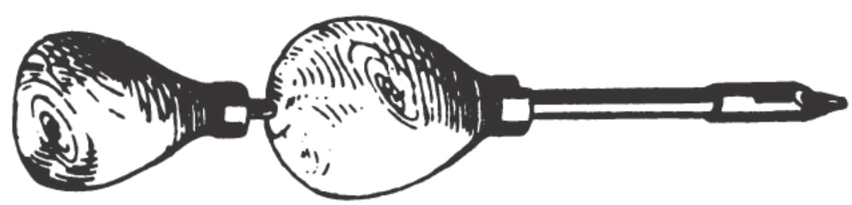


Figure 117. — Royal combination screw driver.

Besides the standard screw drivers, a number of special screw drivers are used in repairing typewriters. Most of the manufacturers supply special screw drivers to be used in work on their particular machines. For example, the Royal has a special combination screw driver, S-10, shown in figure 117, which is used to turn the segment ball race screws on Royals.

## PLIERS

In typewriter repair, a number of different types of pliers are used, including the ordinary wiring pliers, the duck bill pliers, the long round-nose pliers, the long needle-nose pliers, the curved needle-nose pliers, and the parallel flat-nose pliers. (See figure 118.) Besides these, other tools of this type have

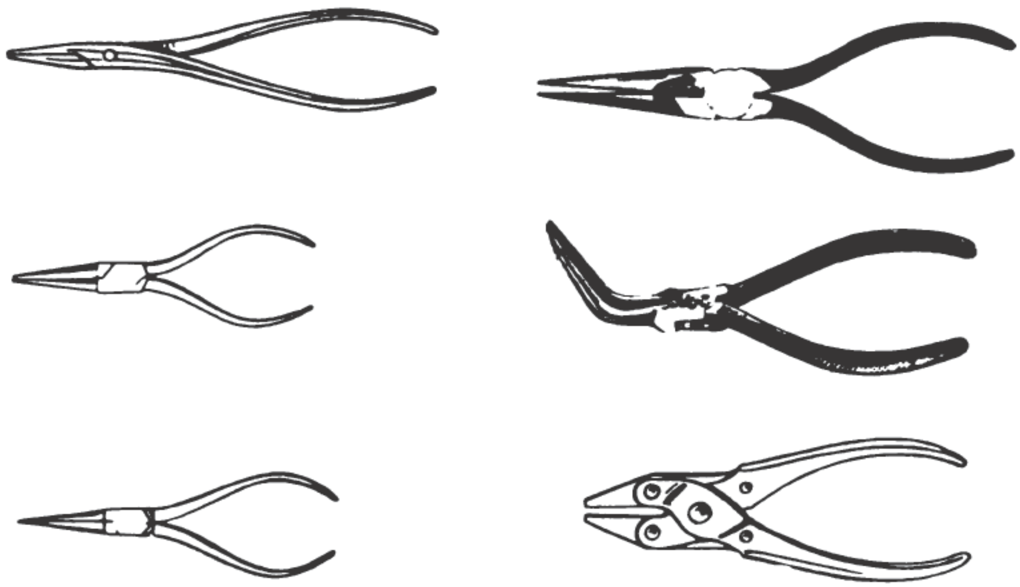


Figure 118.— Some of the pliers used in typewriter repair.

been designed by the manufacturers to do certain jobs. For instance, the nine-prong pliers illustrated in figure 119 have

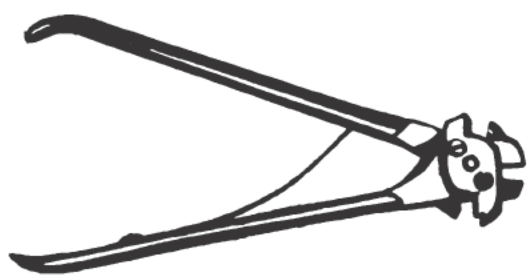


Figure 119.— Nine-prong pliers.

three sets of forming jaws, and are made for forming the key-levers of all the makes. This tool is particularly valuable because it can be used handily in three different positions. The three-prong pliers, made with one set of jaws, is also a very useful tool for making adjustments on all makes of typewriters.

Special keyring pliers (figure 120) are used for attaching and

detaching the keyrings on all typewriters except the Remington which has no keyrings. Specially designed wire cutting pliers, supplied with interchangeable jaws for MAULING and type cutting, are used on all the different makes. (See figure 121.)

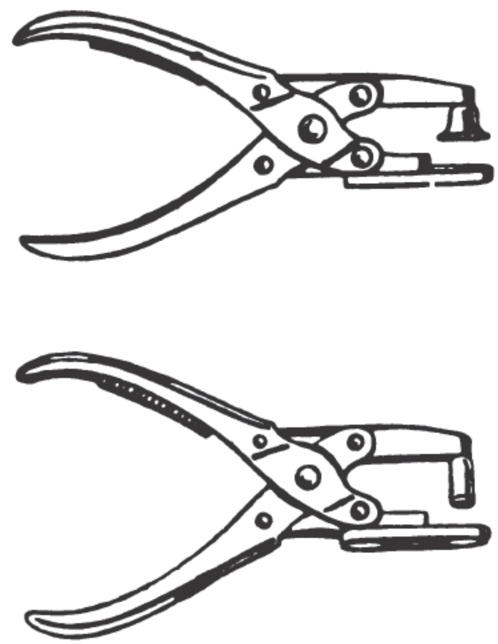


Figure 120. — Keyring attaching and detaching pliers.

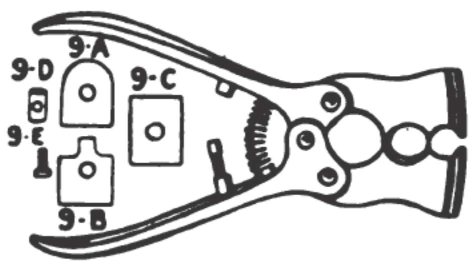



Figure 121. — Wire cutting pliers, with interchangeable jaws for mauling and type cutting.

Special side alining pliers, shown in figure 122, are used in typewriter repair for making side alinements of the type, and the typewriter peening pliers illustrated in figure 123 are very useful for spreading the metal and raising or lowering the keylevers.

Royal keylever bender tools, S-6, shown in figure 124 are a special kind of pliers made especially for the individual adjustment of ring and cylinder typebar levers on that make.

Always clean your pliers at the end of the day, removing all metal filings and handmarks.

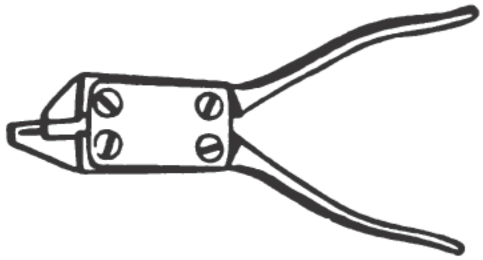


Figure 122. — Side alining pliers.

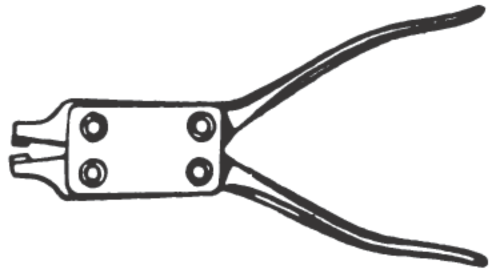


Figure 123. — Peening pliers.

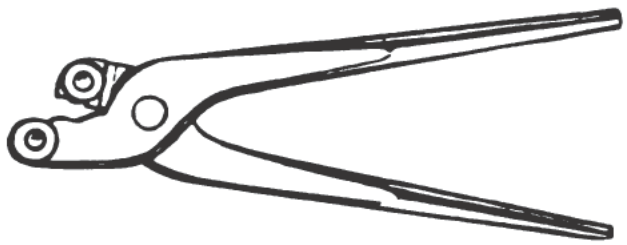


Figure 124. — Royal keylever bender.

## WRENCHES

The wrench is a very important tool in typewriter repair. An assortment of typical typewriter wrenches is shown in figure 125. The ordinary open-end flat wrench with openings of either 3/16 or 5/32 of an inch is probably the most frequently used tool of this type; you can use this wrench on a number of parts on any typewriter.

Besides these standard wrenches, there are many special wrenches used in typewriter repair. Experience will gradually make you familiar with the principal typewriter wrenches, the most important of which are listed below.

*Underwood special wrenches.* — The Underwood escapement wrench, TL-492, illustrated in figure 126, is used for adjusting the Underwood escapement trip. The Underwood backspacer link bender, TL-483, illustrated in figure 127, is used in working on the backspacer arm extension. The Underwood front rod nut wrench, TL-518, illustrated in figure 128, and the Underwood alining wrench, TL-482, shown in figure 129 are also furnished for use on that machine.

*Remington special wrenches.* — Two Remington toggle wrenches, ST-40003 and ST-40004 (see figure 130), are used

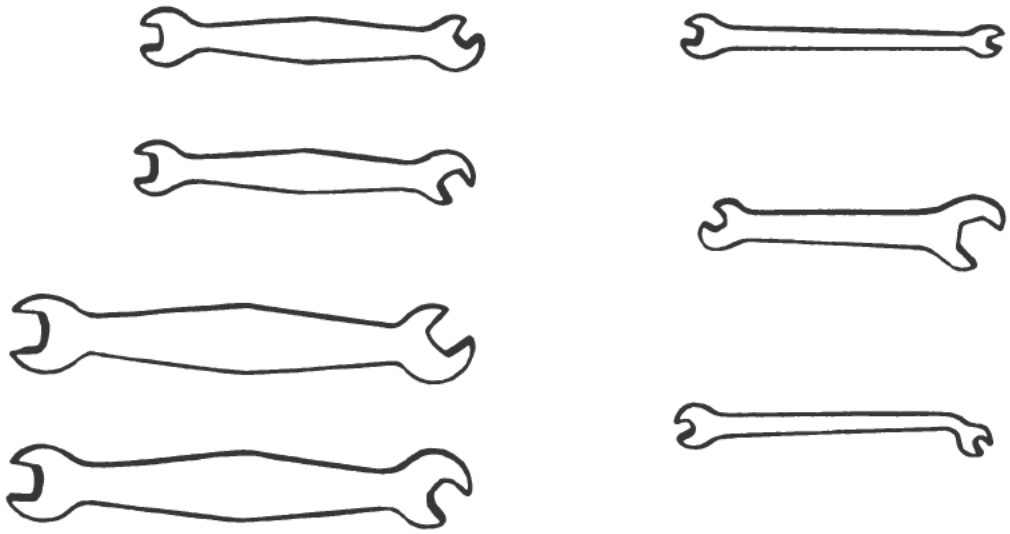


Figure 125.—Typical typewriter wrenches.

Figure 126.—Underwood escapement wrench.

Figure 127.—Underwood backspacer link bender.

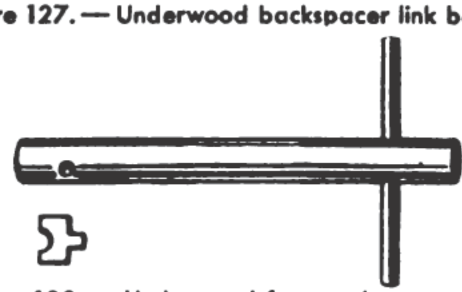


Figure 128.—Underwood front rod nut wrench.

Figure 129.—Underwood alining wrench.

for adjusting the motion and on feet eccentric on the Remington machines. The Remington ST-40001 segment stop screw wrench (illustrated in figure 131), is used for adjusting the Remington back segment stop screw nut.

The front segment stop screw nut on the Remington is adjusted by means of the Remington socket wrench No. 1, ST-40017, in combination with the Remington screw driver No. 40094 (see figure 132). Socket wrenches Nos. ST-40015,

ST-40016, and ST-40021, are used on various other nuts on the Remington.

*Royal special wrenches.* — Royal makes a special ribbon vibrator arm bender, S-39 (see figure 133), for holding and forming the ribbon vibrator.

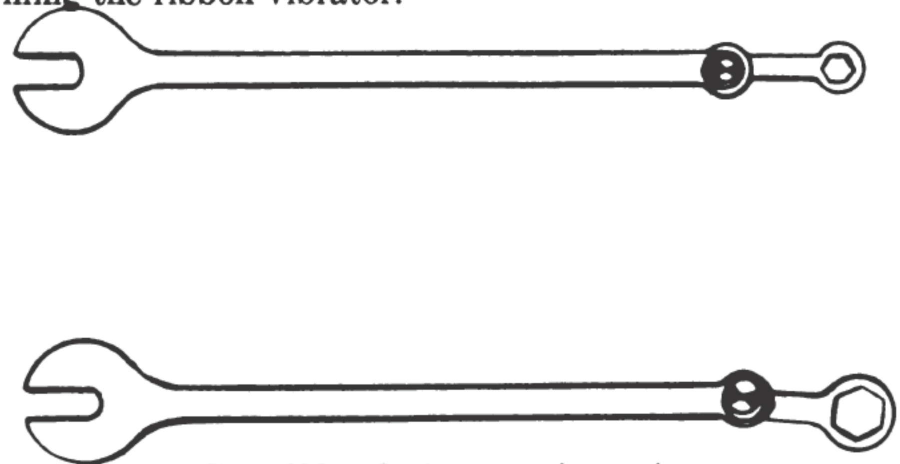


Figure 130. — Remington toggle wrenches.

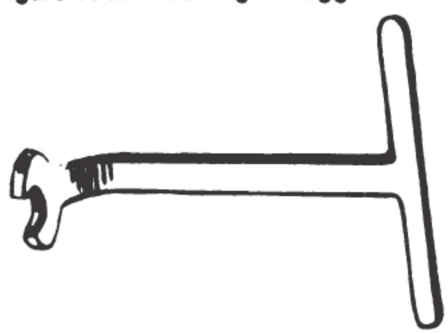


Figure 131. — Remington segment stop screw wrench.

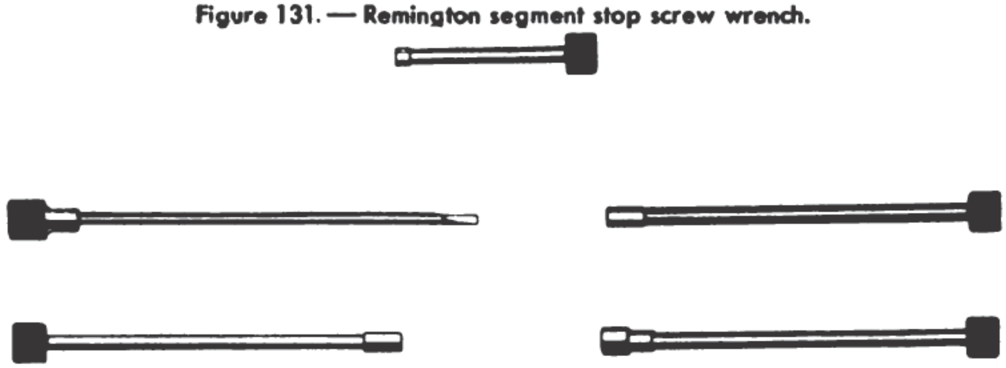


Figure 132. — Remington socket wrenches, with special screw driver.

*L. C. Smith special wrenches.* — A special L. C. Smith escapement wrench, No. 46 (see figure 134) is furnished for adjusting the escapement trip on that machine. Two specially formed

motion wrenches, Nos. 43 and 44 (see figure 135) are also furnished for adjusting the motion on the L. C. Smith typewriter.

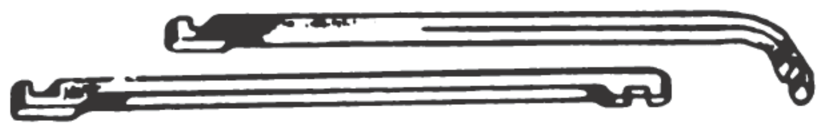


Figure 133. — Royal ribbon vibrator arm bender.

Figure 134. — L. C. Smith escapement wrench.

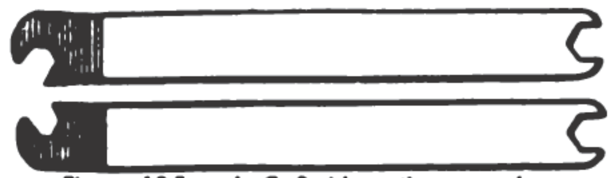
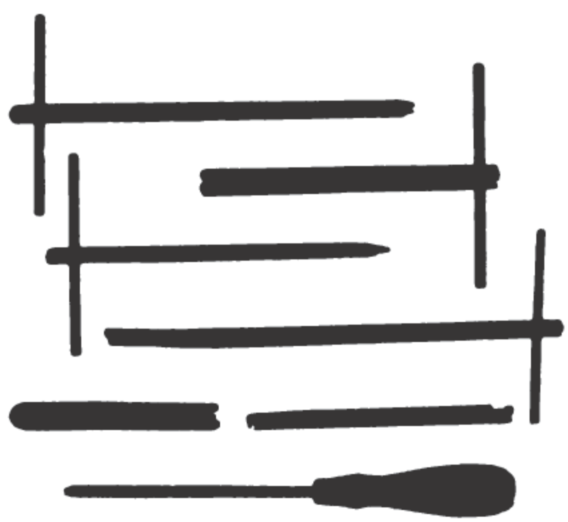


Figure 135. — L. C. Smith motion wrenches.

Always be careful, when working with any kind of typewriter wrench, to use only enough force to loosen or tighten the part that you are adjusting.

## TWISTERS

The key forming tools, or TWISTERS, are really a special kind of wrench. The common types of twisters are illustrated in figure 136. Underwood makes a variety of twisters for use in



forming various parts of the Underwood machine; some of these twisters may occasionally be used for similar operations on other makes.

Different Underwood twisters are used for forming the universal bar and lift rail, the typebars, the actuating lever bracket, the bichrome bracket, the cylinder scale, the keylevers and the connecting levers of the Underwood. As you become more proficient in repairing typewriters, you will learn how to use some of these twisters to good advantage on the other makes of machines.

## SPRING HOOKS

Whenever you must attach a spring onto an inaccessible part of the typewriter, you will use a spring hook (see figure 137.) As in the case of the typewriter screw driver, Instrumentmen

Figure 137. — Spring hook.

usually make their own spring hooks to suit their ideas as to length and curvature of the ends.

## SOLDERING

Since Instrumentmen perform a variety of soldering operations in repairing Navy instruments, a brief discussion of soldering is given here. A more complete discussion of the subject can be found in the Navy training manual, *Use of Tools*, NavPers 10623. Information on brazing is also given below, since you might occasionally have to braze a broken typewriter main frame or carriage frame.

Soldering is the simplest of the processes for joining metals. It is used to join cast, unfabricated metals at comparatively low temperatures. Like and unlike metals are fastened together by using another and entirely different metal as solder. The two metals are joined together without melting either one. Solders are used for joining iron, lead, tin, copper, zinc, and many of their alloys.

Soft solders differ from hard solders in that they are alloys

which can be melted at temperatures below 700° F. Since in soldering, the metals to be joined are not heated to the melting point, the solders must have a melting point lower than that of the metals to be joined. Soft solders, because of their low melting point, flow readily and are easily applied; but they do not have great strength.

Solder is an alloy of two metals: lead and tin. Lead melts at 621° F. and tin melts at 465° F., but 50-50 tin-lead solder melts at 450° F., a lower temperature than either tin or lead. This HALF-AND-HALF solder is rather soft, and is well adapted for instrument soldering work.

Soldering coppers, sometimes incorrectly referred to as IRONS, are used for small soldering jobs. The working end of such a soldering tool is made of copper because that metal is an excellent conductor of heat. The 2-pound and 3-pound sizes are most frequently used. You select the size according to the requirements of the job. As a rule, it is best to pick the largest size that is convenient to handle.

The points of a soldering copper should be rather blunt for efficient heat conduction. The points are shaped by forging — beating them into shape on an anvil while they are hot.

The Instrumentman generally uses an electric soldering copper of the pointed type.

## The ABC's of Soldering

For good soldering, the following rules must be observed:

A. The surface to be soldered must be clean of all grease, oxides, and other foreign matter.

B. The surface to be soldered must be heated to a temperature just hot enough to melt the solder.

C. A flux must be used that will melt at temperatures below the melting point of the solder in order that it will not form pits or cavities in the soldered joint.

D. All traces of corrosive fluxes must be removed after the joints have been made.

## Preparation for Soldering

The first step is to clean the surfaces to be soldered. The

strength of the joint depends on the adherence of the solder to the metals. These surfaces must be free from oxide, grease, dirt, and other foreign matter so that the solder will adhere to the metal. All metals are normally covered with oxides, which increase as the metal is heated to the soldering temperature. The cleaning may be done mechanically or chemically.

To clean mechanically, the surfaces of the metal may be scraped, filed, or rubbed with sand or emery paper.

Usually, the surfaces are cleaned with chemicals. Cleaning by chemical action, with a pickling solution of acid or alkali, is known as fluxing. Ordinary pastes or liquid solutions containing zinc chloride are used for soft soldering. The material holding the flux is evaporated by the heat of the soldering operation, leaving a film of the flux on the work. As the molten solder is applied, the flux is melted, and dissolves the oxides from the solder and the work. When the process is completed, a thin film has been formed protecting the work from further oxidation. Navy Flux Specification 51-F-1b., which comes in ½-pound tin cans, is a good paste soldering flux for soft soldering work.

## USING THE ALCOHOL BLOWTORCH

For direct-flame soldering on small jobs, an alcohol blowtorch is usually employed. This small automatic torch is a self-contained unit and creates its own pressure. The tank is filled about two-thirds full, then sealed. To operate, remove the cap and light the wick. The flame from the wick heats the jet

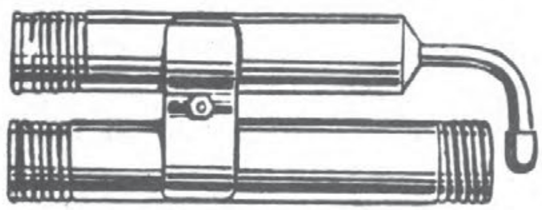


Figure 138. — Alcohol blow torch.

tube, causing the liquid alcohol in the container to vaporize and expand, forcing the alcohol vapor from the jet opening, where it is ignited to form a hot, light-blue flame. A type of alcohol torch used by many Instrumentmen is shown in figure 138.

## THE TYPE GAGE

When a type character is printing more than 0.003 inch above the writing line, it should be resoldered. For this you will need a type soldering gage. Several types of these gages are in common use; most Instrumentmen like to use the gage illustrated in figure 139.

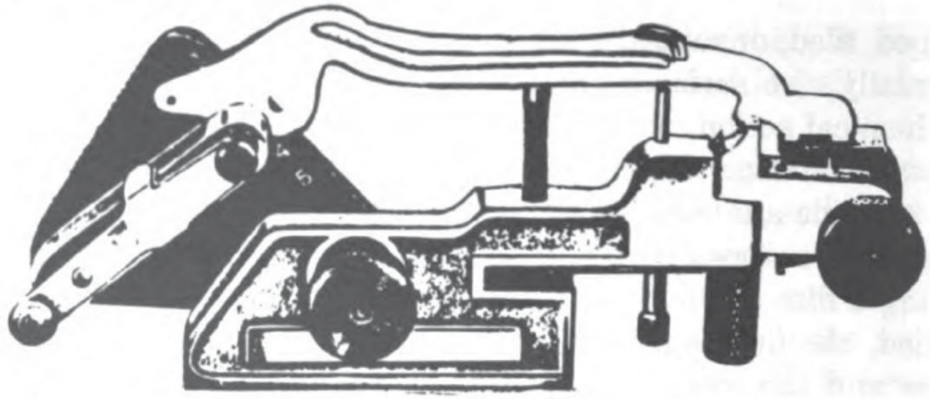


Figure 139. — Universal type soldering gage.

First, remove from the machine the typebar to be resoldered, and also the good typebar which adjoins it. Set the second typebar up in the gage, and tighten all the screws to hold the setting. Then take this good typebar out of the gage and place in it the typebar to be resoldered. Use an alcohol blowtorch to heat the point where the typehead is soldered to the typebar, until the solder melts; then, using the tip of a screw driver, carefully move the typehead backward or forward, as required, until it is back in line. The repaired typebar is then replaced in the machine, and the type position is tested for alinement. It may be necessary for you to repeat this operation two or three times before you get the typehead back into correct alinement.

If the typehead is damaged and has to be replaced, melt the solder and lift off the damaged typehead. Apply enough heat to remove all traces of the old solder, then clean the end of the typebar and the slot in the typehead. Fit the typebar into the slot of the typehead, then melt a small amount of solder down to the place where the typebar fits in the slot. After the soldering has been completed, wipe off all traces of flux and solder

from the new joint. As before, several trials may be required before the correct type position is obtained.

You'll need a lot of experience before you can resolder type efficiently, so practice the operation whenever you have time.

## BRAZING

Brazing is the method of joining metals by means of a molten alloy with a melting point above 1000° F. The melting point of a brazing alloy, like that of a soldering alloy, must be below the melting point of the metals being joined. Except for the higher melting temperature, brazing is about the same as soft soldering. The brazed joint is much stronger than the soft soldered joint, and it can stand a much higher temperature.

Three types of filler alloy are used in the brazing process: silver alloy, brass, and bronze. Silver brazing alloys are commonly called "silver solders." Silver solders contain over 50 percent silver, and have a melting point of 1450° to 1750° F. Silver alloys are alloys of silver, copper, phosphorus, cadmium, and nickel. The percentage of these various metals determines the color of the alloy, its strength, and its melting point.

Brazing is usually done with a long thin torch known as a gas blowpipe. The end or blowpipe section is a tube within a tube; one tube furnishes the gas for the flame, and the other tube supplies compressed air or oxygen. Valves on the other part of the blowpipe control the supply of gas and air.

## GETTING READY TO BRAZE

Clean, well-fitted joints are necessary for satisfactory brazing. All parts to be brazed must be thoroughly cleaned. Surface scale or oxides should be removed either by chemical or mechanical means (sanding, filing, or brushing with a stiff wire brush). Chemical cleaning is done with a FLUX, or cleaning agent, as in soldering.

## FLUX FOR BRAZING

The flux used should be fluid and active at the brazing alloy melting point. A flux should remain stable, not changing rapidly to vapor in the brazing temperature range. It should

dissolve all oxides and remove them from the brazing surfaces, and it should also adhere to those surfaces while they are being heated. Finally, it should be easy to remove after brazing. Navy Flux Specification 51F4, commonly known as "HANDY FLUX," is a very satisfactory one for brazing instrument parts.

Heat control is the most difficult part of brazing. To become a good brazer, you must learn to manipulate the torch. That takes experience. By watching others, and putting in plenty of practice yourself, you can learn to do a very acceptable job of brazing.

## CLEANING AND OILING

The typewriter, like any other mechanical device, should be cleaned and oiled periodically, depending of course upon how much usage the machine receives, and also upon climatic conditions where the machine is located.

Cleaning and oiling operations are necessary factors in keeping the machine in good working condition. They are extremely important steps in the typewriter casualty analysis.

Cleaning solutions and processes will vary somewhat wherever you may go. In the process described in this manual, three different cleaning solutions are employed. One solution is made up of one part magnasol, three parts of varsol, and five parts of water. The second solution is made up of 80 percent of paint thinner and 20 percent of lubrication oil. The third solution is alcohol, and is used for cleaning the rubber parts of the machine.

Navy standard cleaning solution No. 970, stock No. 51-C-1569-40, which comes in one-gallon containers, is also very good for degreasing typewriters (first solution). If that stock item is not available, substitute items No. 946 or No. 947 may be used in its place.

The first step in cleaning is to disassemble the typewriter. This disassembly process for the various makes of machine is explained in chapters 9, 10, 11, and 12. The next step is to make sure that all rubber and felt pieces have been removed from the machine. Then brush or blow the loose dust or dirt from the machine and its parts. By doing this, you will get better service from your cleaning solution of magnasol, varsol,

and water, since the solution will stay clean for a longer period.

Next, immerse your machine in the magnasol solution, making sure that no rubber or felt pieces are put into the solution. For easier cleaning of the machine and its parts, it is a good practice to insert the nozzle of the spray gun into the solution, and then under a low air pressure, agitate the solution so as to enable it to reach the different parts.

The period of time during which the machine and its parts are left in this solution depends upon how dirty the machine is. The usual time limit is from 5 to 10 minutes.Once the machine is clean, it should be taken out and rinsed under hot water, to free it of all traces of the solution. Then with the spray gun, using compressed air, blow off all excess water.

Your next step is to spray a second solution, composed of paint thinner and lubrication oil, onto and in the whole machine and its parts. This provides a coat of oil which will aid in the lubrication of the machine. With compressed air, blow off all of the excess second solution, leaving only a light film of oil.

All spraying done in this process should be done in a spray booth. Spray booths also will vary, from place to place, in size and shape. A typical spray booth is shown in figure 140. Whatever size or shape of spray booth you have or make, always be sure that you have a good suction fan to rid the booth of dust and dirt and the fumes from spraying. A typical spray gun, with a suction hose to pick up your solution, is shown in figure 141.

The cleaning of the cylinder and the feed rolls depends on their condition. If the cylinder is too hard, too pitted and grooved, or too swollen, it should be replaced. The diameter of the cylinder is different in the four types of machine described in this manual. The cylinder should never be allowed to become undersized by more than 0.010 inch. The sizes of the cylinders in different makes of machine are listed below:

Underwood .................... 1.750-inch diameter
Remington .................... 1.594-inch diameter
Royal ........................ 1.486-inch diameter
L. C. Smith .................. 1.750-inch diameter

If a cylinder is not too hard, grooved, or swollen, it may be

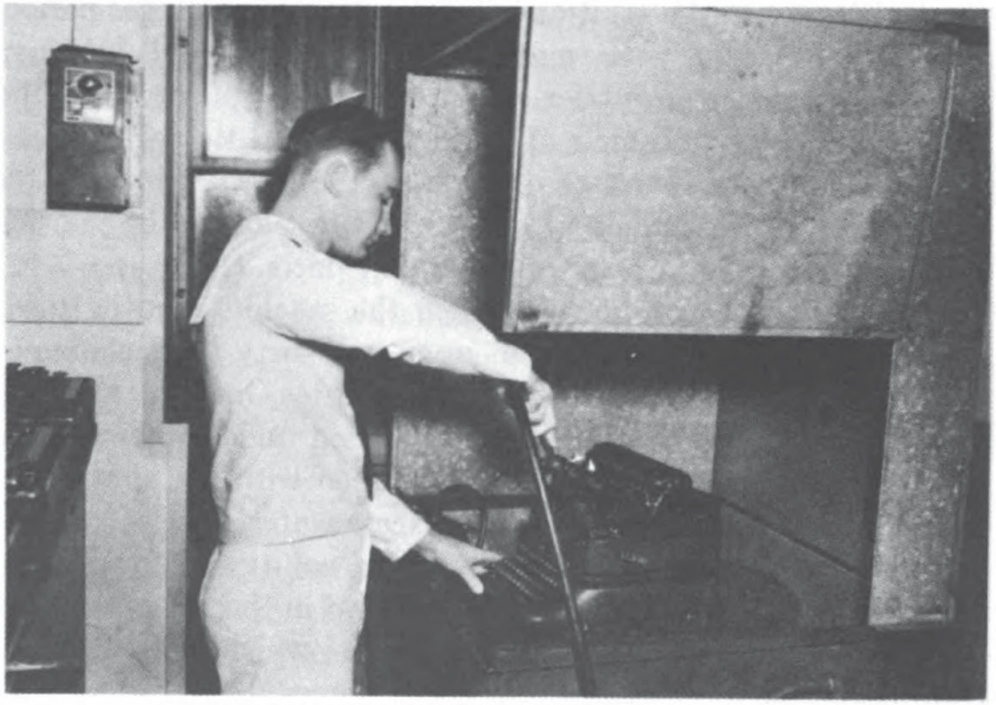


Figure 140. — Cleaning typewriter in spray booth.

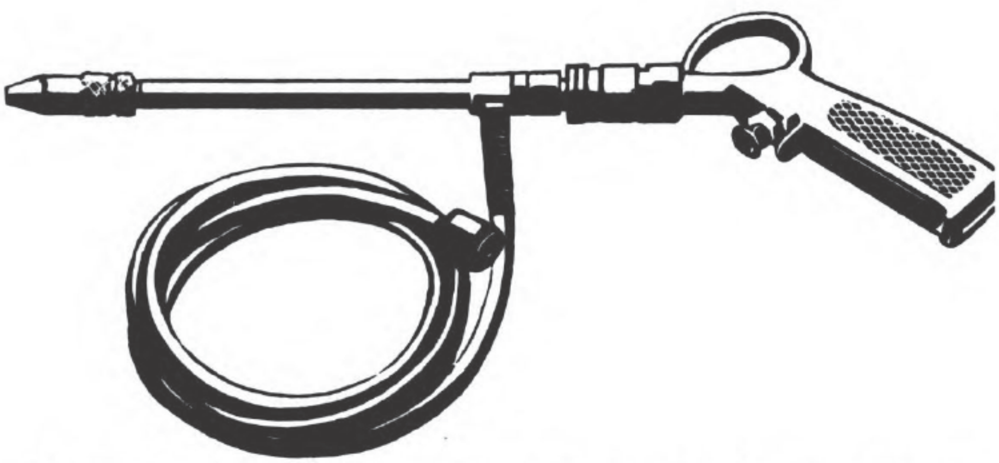


Figure 141. — Air gun with flexible suction hose, used in cleaning typewriters.

smoothed down by using alcohol and emery cloth. Take a piece of emery cloth in your hand and, starting at one end of the cylinder, twist and at the same time slide the cylinder through the emery cloth until you have reached the other end. Always be sure that the cylinder is the same diameter throughout its whole length.

The oiling of a typewriter, like the cleaning, depends on the climatic condition and on how much the typewriter is used. If a typewriter is just to be oiled, be sure to clean it as far as possible. This will prevent the dust, dirt, and oil from forming a gummy substance.

Oil should be applied only to pivot points, bearing surfaces, et cetera. Be careful to apply it in moderation, and be sure that when the oiling is finished, all excess oil is wiped away. Keep the oil from getting on the rubber parts, the ribbon, and any place in the machine where it might stain the paper.

After you have completed the cleaning and oiling process, reassemble the machine, according to its make, by following the instructions given in chapters 9, 10, 11, or 12 of this manual.

## QUIZ

1. What are nine-prong pliers and when are they used in typewriter repair?
2. How are peening pliers used in typewriter repair?
3. What are TWISTERS?
4. What is soldering?
5. What are the ABC's of soldering?
6. What is a flux?
7. Describe the operation of an alcohol blowtorch.
8. What is the type soldering gage?
9. What is brazing?
10. Which three cleaning solutions are commonly used in Navy typewriter repair?
11. Are cylinder diameters the same for all makes of typewriters?
12. How would you smooth down hard, grooved, or swollen rubber on a cylinder?

Chapters 9 through 12 (pages 168 through 300) have been deleted from this reprint.

## CHAPTER 13

# PRESSURE AND VACUUM GAGES

## CONTROL INSTRUMENTS

Control instruments have a dual mission on shipboard. They indicate to the engineering personnel the immediate condition of the machinery in use, thereby making prompt regulation of the machinery possible and giving warning of any abnormal conditions such as excessive pressure, temperature or speed. They furnish information for the engineering log — data that can be analyzed to determine the current operating efficiency of the engineering plant and to suggest future improvement. Obviously, equipment of this kind is extremely important aboard ship. Its maintenance in first-class operating condition warrants the most careful and conscientious attention of the Instrumentman.

Control equipment includes all of the following indicating

gages — pressure and vacuum gages of all types, manometers, thermometers, thermal alarms, pyrometers, tank level indicators, fluid meters, revolution counters, salinity indicators, and combustion control equipment.

The Navy Training Course on *Basic Machines*, NavPers 10624, contains a whole chapter devoted to force and pressure, as well as other valuable information that you should know about levers, springs, gears, and other mechanical devices used in instruments. If you have not yet read this manual, get a copy and read it soon. It will greatly increase your knowledge of instrument theory and design. Also, you will find it worth your while to read *Aircraft Instruments*, NavPers 10333, which gives an understanding of why and how aircraft instruments function. You might be called on someday to repair some of those instruments.

We will begin our study of the control instruments used in the Navy with a detailed discussion of pressure and vacuum gages.

## DIAL SIZES

The size of the gage is determined by the nominal diameter of the dial. The Bourdon-tube pressure and vacuum gages most widely used on naval vessels are of the 4½-inch, 6-inch, 8½-inch, and 12-inch dial size. The earlier models have polished or painted metal cases; the newer gages have black plastic (phenol) cases. The 4½-inch size should be used for replacement of the old style 6-inch case. Smaller 2½-inch and 3½-inch dial gages of this type are also used on shipboard for indicating vacuum; they are also used with oxygen and acetylene containers, and for refrigeration and carbonation service.

## BOURDON-TYPE GAGES

For measuring pressures of 15 pounds per square inch and up, the Bourdon type of gage is the most satisfactory. The principle of operation of this gage is shown in figure 243.

A thin-walled, oval-shaped tube is bent into the form of a "C" inside the gage, its fixed end fitting into a stationary base connected with a source of pressure such as a boiler system, so that the pressure in the boiler will be transmitted to the tube.

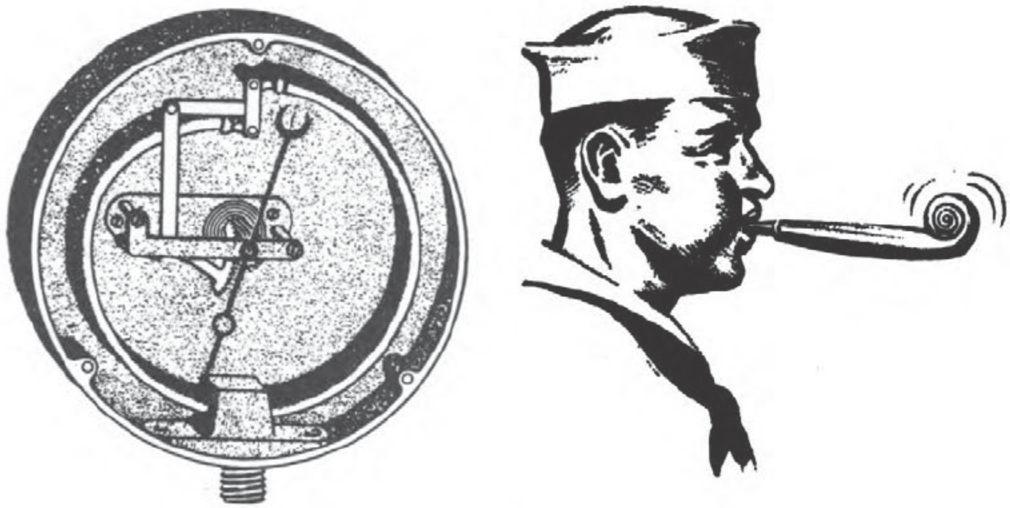


Figure 243. — The Bourdon gage and its principle of operation.

Like the paper *snake*, the metal tube tends to straighten out when the inside pressure is increased. As the tube straightens, the pointer is made to move around the dial. Phosphor-bronze seamless tubes are used in these gages for pressures up to 100 p.s.i.; for pressures in excess of 100 p.s.i., chrome variation steel tubes are employed.

The standard Bourdon-type pressure gage is shown in figure 244. The Navy equips all of these gages with a red extra hand, as shown, to indicate normal working pressure. The individual parts of this type of gage are shown in figure 245. The independently mounted rotary gear movement, which is the other important element of this kind of gage, is illustrated in figure 246. These gages are used with steam, air, water, oil, or other fluids. When the gage is used for steam pressures, a gooseneck siphon, or loop, filled with water, must be installed between the gage and the line so that only water will enter the gage.

## VACUUM GAGES

A Bourdon-type vacuum gage commonly used for indicating vacuum in inches of mercury (pressure below atmospheric) on auxiliary condensers, is illustrated in figure 247. Vacuum gages indicate pressure below atmospheric pressure, while pressure gages indicate the pressure above atmospheric pressure. Atmospheric pressure, or zero gage pressure, is equal at sea level to approximately 30 inches of mercury, or 14.7 p.s.i. absolute.

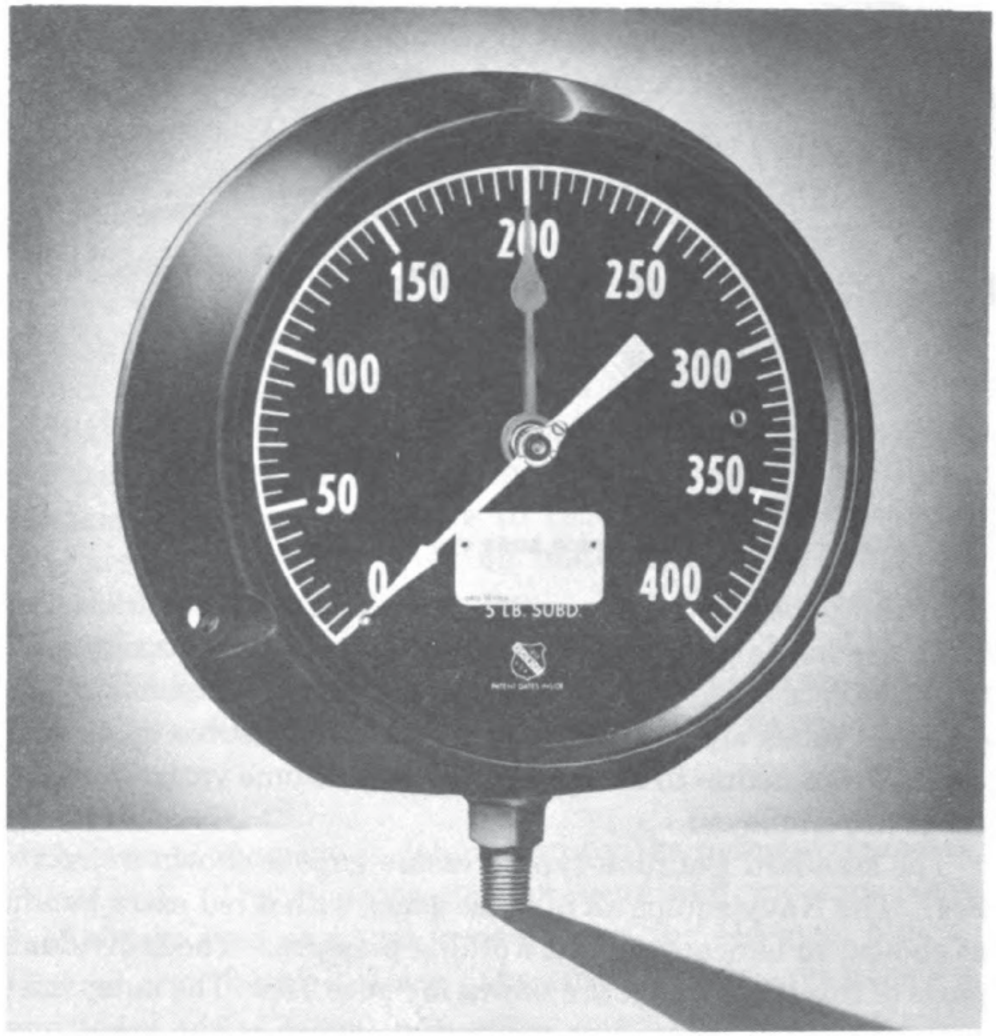



Figure 244. — Navy-type Bourdon pressure gage (phenol case).

To change gage pressure, in pounds per square inch, to absolute pressure in the same units, add 14.7, or roughly, 15 to the gage reading. To change from absolute pressure, in inches of mercury, to pounds per square inch, multiply by the conversion factor, 0.4912 (a column of mercury 1-inch high exerts a pressure of 0.4912 p.s.i.). For example, 50 p.s.i. gage equals 65 p.s.i. absolute (approximately). A vacuum of 14 inches of mercury, with a barometer of 30.29 inches, gives an absolute pressure of 16.29 inches of mercury $(30.29 - 14 = 16.29)$. Multiplying by the conversion factor of 0.4912, 16.29 inches of mercury equals 8 p.s.i. absolute pressure.

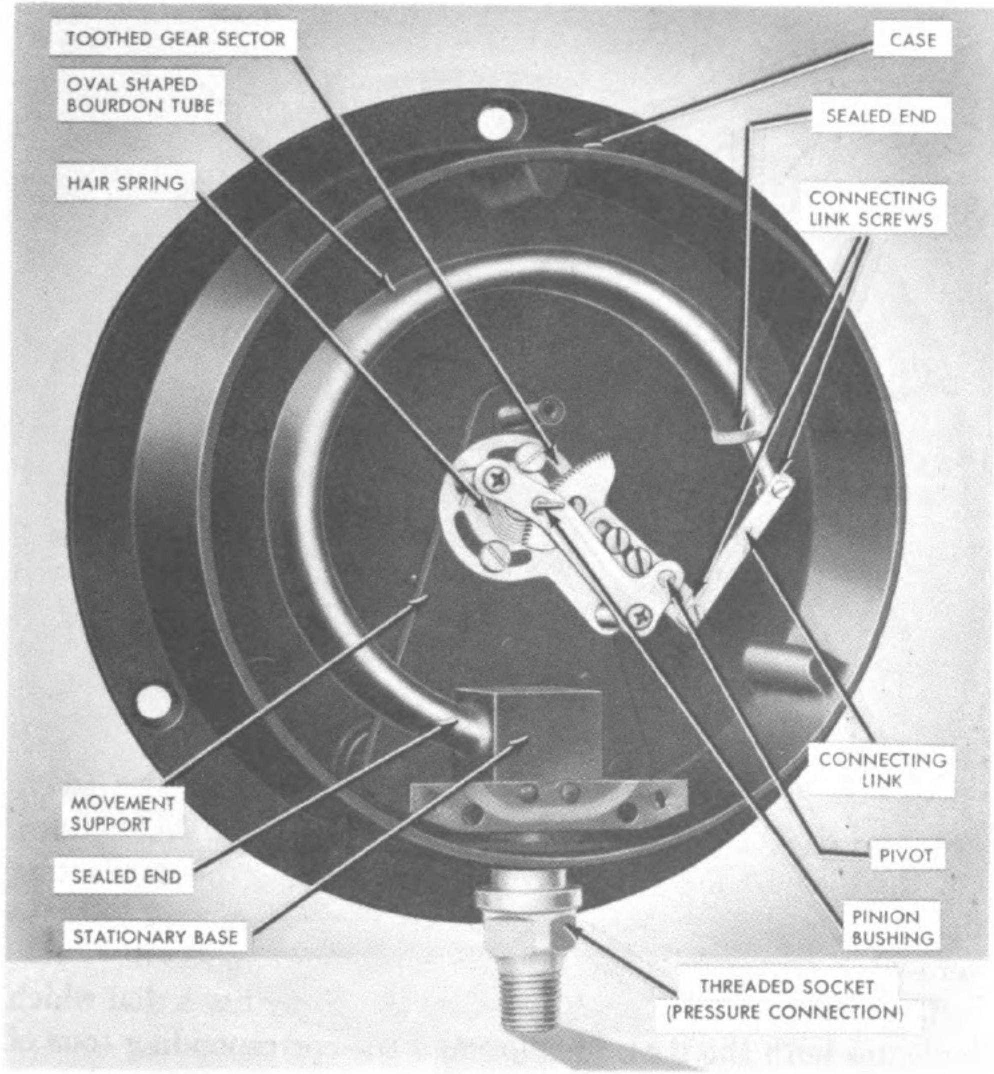



**Figure 245. — Interior of standard Bourdon gage, with parts identified.**

## COMPOUND GAGES

Compound gages employ a single Bourdon tube of such great elasticity that its movement allows measurements of vacuum at the left of a zero point and of pressures to the right of it. (See figure 248.) Gages of this type are often used to indicate the gage pressure and the varying vacuum conditions in the lower pressure stages of turbines.

## HYDRAULIC GAGES

The Bourdon gages used to indicate the heavy pressures on hydraulic rams, such as those employed on the ship's steering

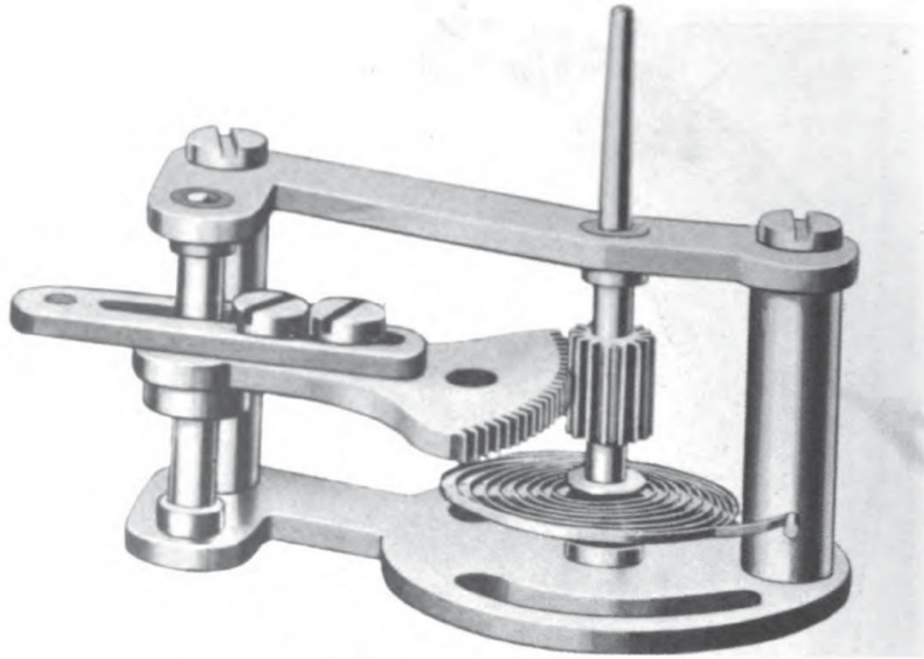


Figure 246. — Rotary geared movement.

gear and anchor windlasses, are specially made for that service. On these hydraulic gages, as they are called, the connecting link is slotted to prevent the pointer from slamming back to zero when the pressure on the ram is suddenly released.

The hydraulic gage model used by the Navy has a dial which indicates both the p.s.i. pressure and the corresponding tons of load on the ram. (See figure 249.) It also has a maximum pointer that is carried up by the main pointer to show the highest pressure reached during an operation. If the pressure is allowed to go too high, it can thus be immediately detected. This maximum pointer is set by means of a knob projecting through the glass face of the dial.

## DUPLEX GAGES

A duplex gage is one in which two separate Bourdon-tube mechanisms are installed with two pointers both swinging across the same scale, each movement acting independently and indicating a separate pressure.

(See figure 250.) These gages are often used in the engine

Figure 247. — Vacuum gage, Bourdon-type.

room to show that the lubricating strainers are open. When one of the mechanisms is connected to the strainer inlet and the other to the outlet, a clogged strainer will be indicated by a noticeable pressure difference.

## DIFFERENTIAL PRESSURE GAGES

Differential pressure gages are equipped with two Bourdon-type tubes, and measure the difference in pressure between two

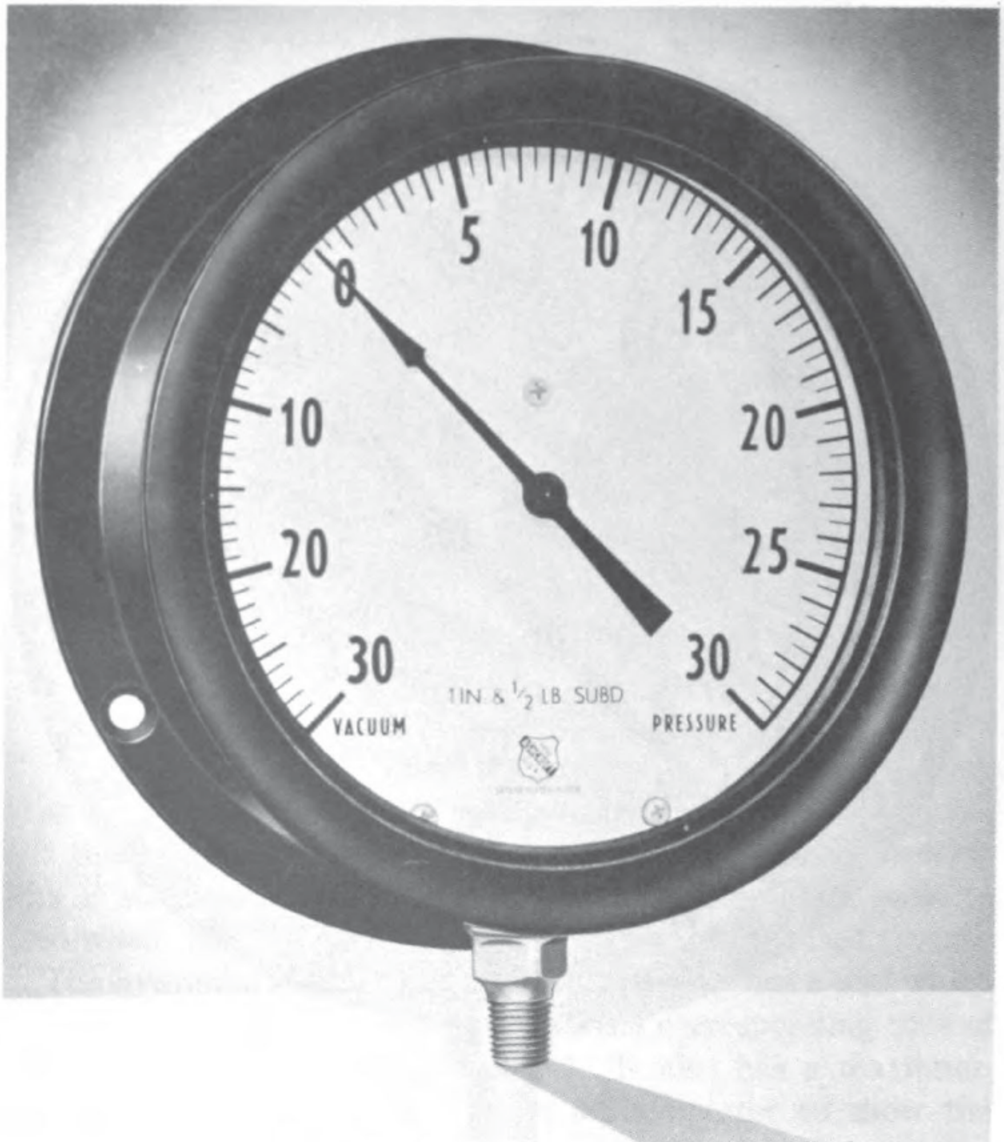



**Figure 248. — Compound gage, Bourdon-type.**

pressure lines. These gages have the conventional-type dial, with the zero at top center, the dial reading both clockwise and counterclockwise. When the pointer indicates on the right side of the dial, the pressure from the right-hand socket connection is higher than the other pressure, and vice versa. These gages are also made with the zero at the lower left-hand side, with one dial reading clockwise. On the latter type of differential gage, the pressure must be applied first to the high-pressure connection and then to the low-pressure connection.

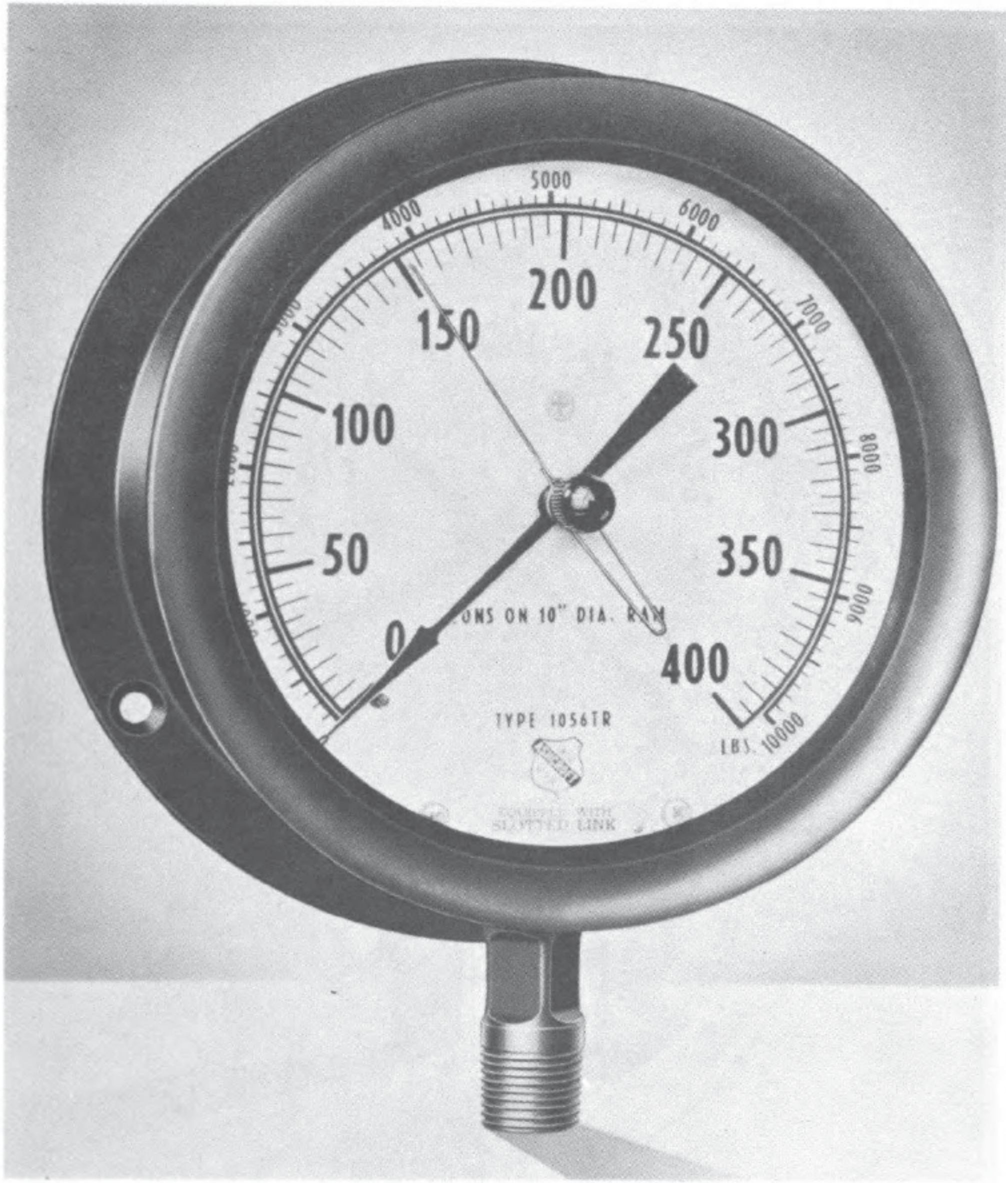



Figure 249. — Hydraulic gage, Bourdon type.

## DEPTH GAGES

Submarines in the Navy are equipped with special pressure gages designed to measure the depth of the boat below sea level. These depth gages are of the shallow-type 16 inch size and employ a double Bourdon tube so as to give extremely accurate readings over the full face of the dial. Some of these depth gages have a special bellows connected into the Bourdon tube mechanism in order to compensate for the pressure inside of the boat; this type of gage is known as a compensating depth

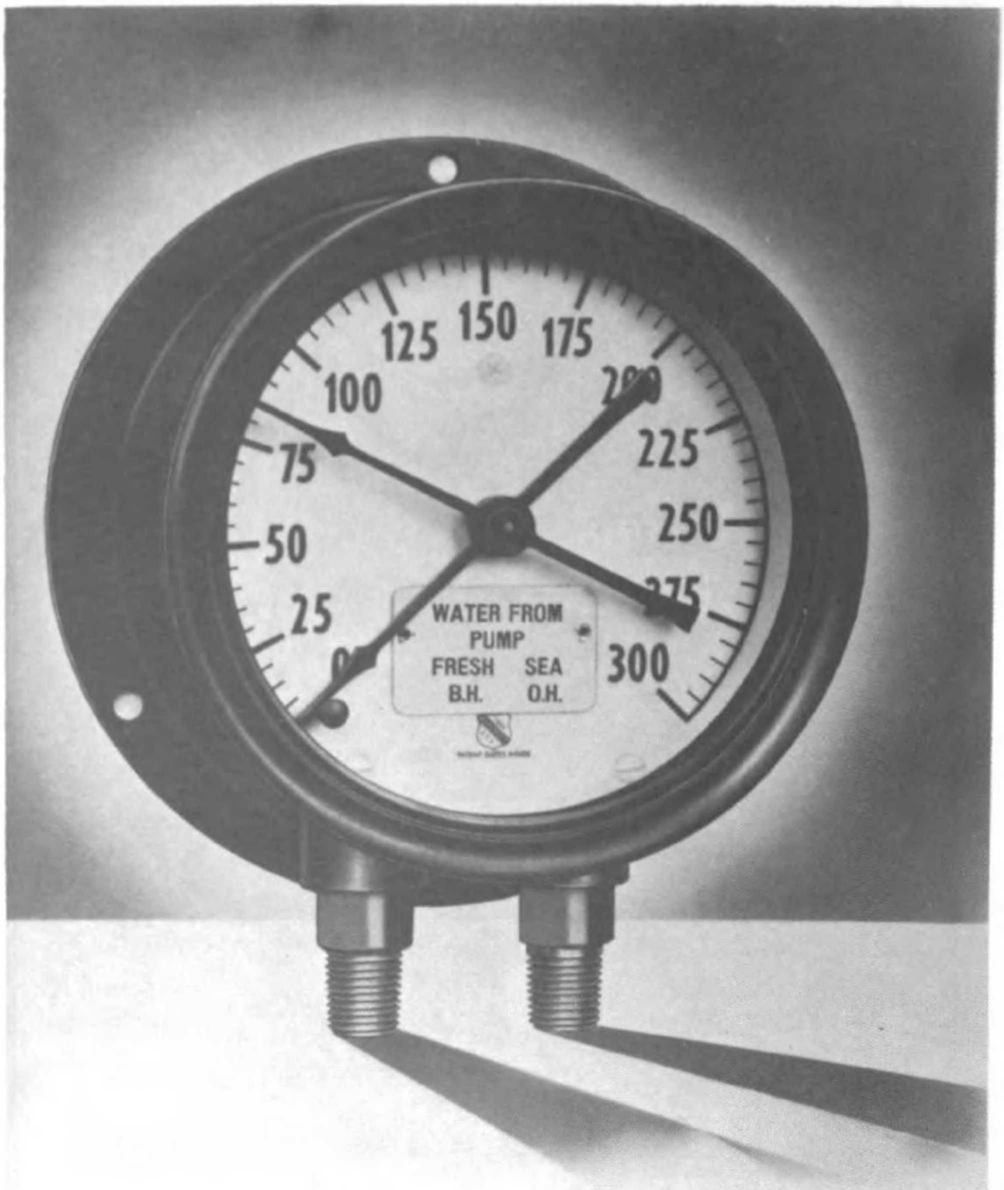



Figure 250. — Duplex gage, Bourdon-type.

gage. The procedures for repairing and calibrating depth gages are the same as those used on any of the other Bourdon gages.

## ADJUSTING THE BOURDON GAGE

The conditions commonly encountered that require adjustment in these gages are as follows:

1. *Pointer calibration.* — Remove the bezel ring and glass

plate, or the snap ring on plastic cases, and adjust the pointer to agree with the desired standard by turning its micrometer adjustment until the pointer is brought to the nearest possible agreement over the desired range. (The pointers on a few makes of these gages can be adjusted from the back, without removing the first cover.)

2. *Sticky or sluggish action.* — If this occurs, either throughout the scale or at certain points, clean out all bearings and gear teeth, and adjust the hairspring so that all backlash is eliminated. (Too much hairspring tension will cause friction and drag.)

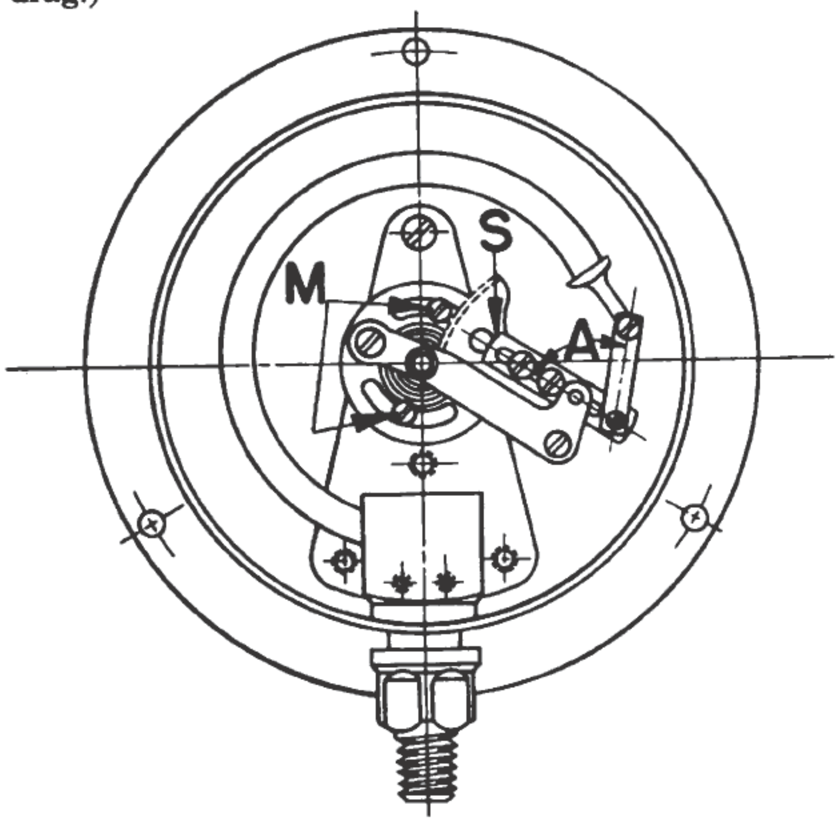



Figure 251. — Pointer adjustment diagram.

NOTE: — When it is necessary to remove the pointer to get at the interior of the gage, the pointer puller supplied with the gage testing apparatus should be used. The pointer should be reinstalled with care so as to avoid damage to the gage.

3. *Incorrect rate of motion.* — A Bourdon tube may change slightly with continued service so that its motion for a given

pressure is more or less than it was. By moving slide $S$ (figure 251) you can change the rate of motion and compensate for such a condition. Push the slide $S$ OUT when the pointer moves too fast; push it IN if the pointer moves too slowly. When the slide is properly positioned, tighten the slide screws.

4. *Angle A adjustment.* — Even with slide $S$ set to the best location, the angle of pull $A$ must be just right or the pointer will travel too fast at either the low or the high end of the scale. By loosening the two screws at $M$, the whole movement may be rotated to give the desired angle $A$. If angle $A$ is too acute, the pointer will travel fast on the first part of the scale and slowly on the last part. For example, if a gage reads perfectly from zero to the top of the dial (one-half of the scale) but from there on travels gradually slower, the remedy is to increase angle $A$ little by little until the hand begins to go faster for the last half of the scale. This rotary adjustment is especially useful when a new movement is being installed in an old gage. If it is not possible to make a gage read correctly over the entire scale, adjust it so the reading at the working pressure is correct, and make a table showing the correction to be applied for other readings.

## MAINTENANCE

Replace all broken glasses in Bourdon gages promptly so as to keep dirt out of the working bearings and the teeth of the movement mechanism. Always install a new felt gasket between the glass and the bezel ring in such cases. Tighten all screws; loose screws due to shipboard vibration cause much trouble in these gages.

Never oil gage movements or linkages; oil attracts dirt and becomes gummy, causing the gage to act sluggish and give inaccurate readings. When removing any part of a gage, care must be taken not to bend or distort any of the elements, thereby increasing friction of the moving parts with a consequent loss of accuracy.

When putting a recalibrated gage back into service, apply the pressure slowly. Do not open the pressure gage cock or valve too quickly — a severe strain on the Bourdon tube might rupture it or shorten its life.

Gages should not be located where they are subject to high heat vibration, moisture, or corrosive fumes. If these conditions are unavoidable, replace old gages, so located with new gages in phenol-plastic cases, which are resistant to most corrosive fumes and cannot rust. When installing repaired gages always replace the used rubber gasket with a new one. Gage dials should not be polished. Whenever practicable they should be marked to indicate the purpose of the gage. Except for high pressure gages, which are tested once a year, all pressure gages should be tested at least once every 6 months or whenever it is suspected that they are not accurate. After each test a certificate should be placed inside of the glass face showing the date of test and adjustments necessary, if any, for correcting the indications. And if you remount the gage yourself, be sure that the piping connection below the gage is tightly pulled up. Incorrect installation has accounted for more poor performance of pressure and vacuum gages than any other single cause.

Vacuum gages should be tested at least every 9 months, preferably every 6 months.

Spare gages should be stowed where they will not be subjected to moisture or to severe shocks and jars.

> CAUTION: — Since pressure and vacuum gages will not indicate correctly unless their piping systems are perfectly airtight, always paint the threads of the socket of every new or repaired gage with white lead, lacquer or other suitable sealing compound, so as to assure an airtight installation.

A gage board in a ship's engine room is shown in figure 252. Pressure and vacuum gages of different types are mounted there, with speed indicators and revolution counters in the center above the throttle controls.

## GAGE TESTERS

*Deadweight tester.* — Gages are tested either by comparing them with a standard test gage or with a gage-testing apparatus. As an Instrumentman you will use both of these methods. A standard gage-testing apparatus is shown in figure 253. This device, known as a deadweight tester, is essentially a hydraulic

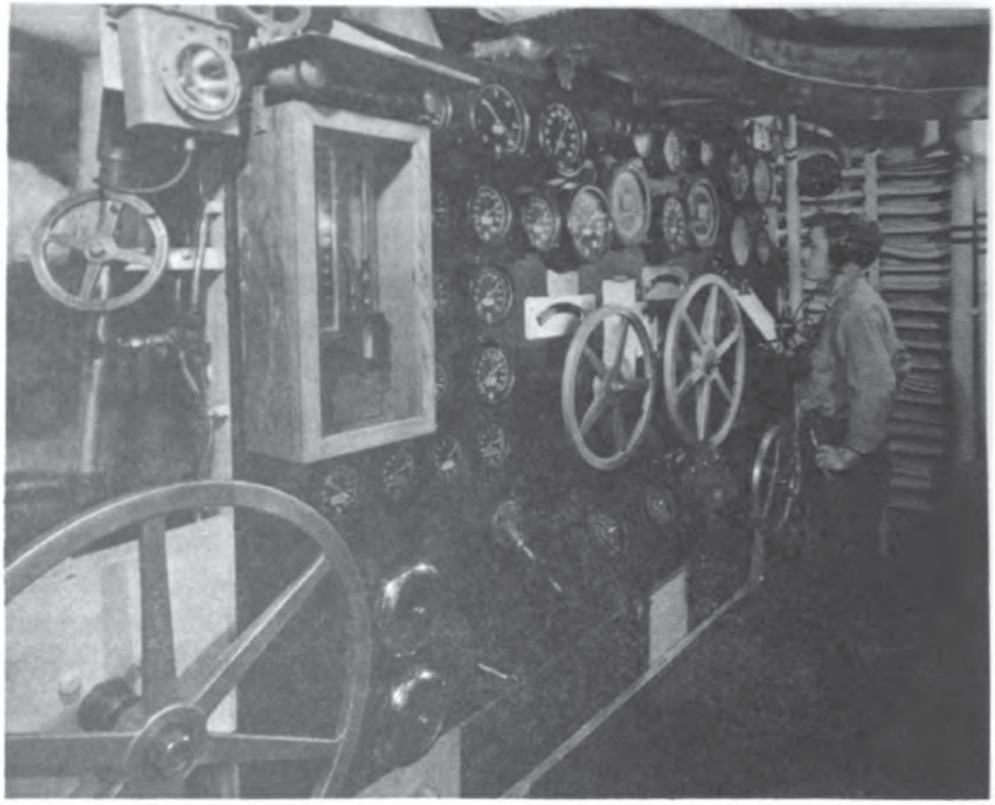


Figure 252. — Checking gages in engine room of USS *Denver* CL58.

balance. It operates on the principle of subjecting the gage under test to a hydrostatic pressure created by applying weights to a piston *F* (figure 254) of known area. The piston is accurately fitted into a vertical cylinder *G*. The weighted piston applies pressure to a fluid (usually a light mineral oil) in the cylinder, which in turn is transmitted to the gage by the piping *J*, through the control valve *D*. Deadweight testers are available in several sizes, usually up to 500 p.s.i. and above 500 p.s.i. Be sure to check on the capacity of a tester before you begin to use it, so as to obtain the most accurate test results.

The piston itself usually corresponds to an initial pressure of 5 or 10 pounds, and 5-, 10-, and 20-pound weights are provided with each set. Weights are added as desired, and the reading of the gage is compared with the pressure being created by the calibrated weights. Cylinder *A* is a simple pump provided for the initial filling of the instrument. Cylinder *C* and piston *H* are used to maintain the correct vertical position

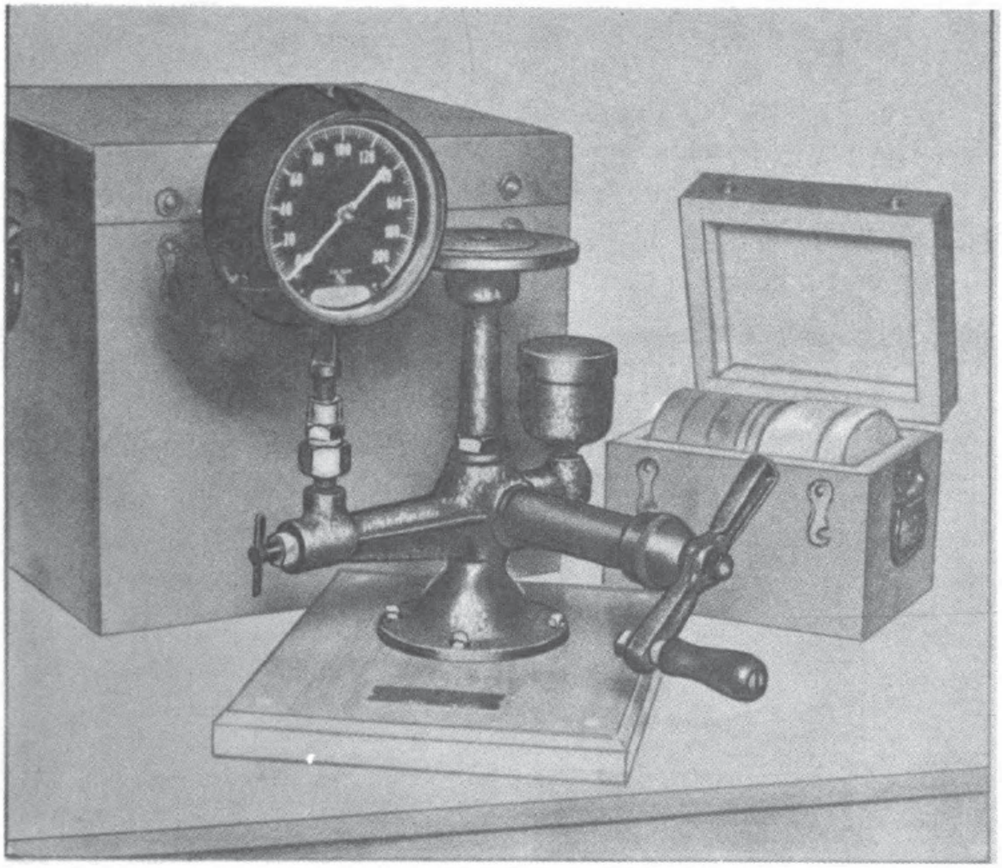


Figure 253. — Deadweight pressure gage tester.

of the weight platform of piston *F* (about 2 inches above cylinder *G*) when calibrating a large gage. During tests the column of weights is kept revolving by hand to eliminate the possibility of friction error.

To make a test with the deadweight gage tester, connect the gage to the testing apparatus and fill the tester with oil. Now level the tester. Insert the piston in the cylinder and note the reading on the gage. Add weights individually as desired, gently rotating the piston during this operation to overcome the frictional resistance between the piston and the cylinder wall. If the gage reading increases in amounts equal to the weights as added, and if the reading of the gage is equal to the pressure represented by the total weights added, then the gage is in adjustment. If not, further adjustments will have to be made on the gage.

When testing the higher pressure gages, an additional step

may be necessary. Most gage testers have an auxiliary cylinder fitted with a piston connected with the main cylinder. Before starting to test a large gage, the auxiliary piston should be screwed out, allowing both the auxiliary and main cylinder to fill with oil. If, during the test, the main piston descends to its full length, screw in on the auxiliary piston and force the main piston up as far as is necessary to allow sufficient weights to be applied to complete it.

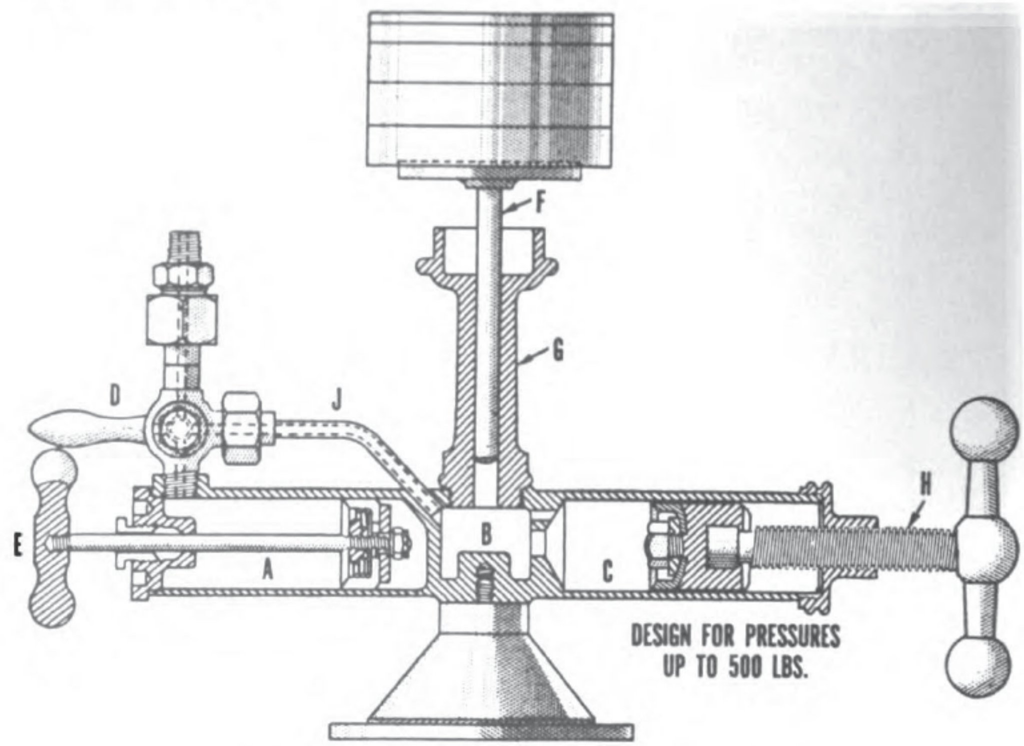



Figure 254. — Interior design of deadweight tester.

If it is found that the pointer of a gage travels too far, or not far enough, as each additional weight is added, the fault must be corrected by altering the leverage to change the ratio of movement between the tube and the pointer. The method for this correction has been described above.

When the test is completed, remove the weights one or two at a time, and as the main piston rises, withdraw the auxiliary piston to provide space for the returning oil. Finally, remove the gage and drain from it any remaining oil.

If the tester is to be secured, remove the main piston. With

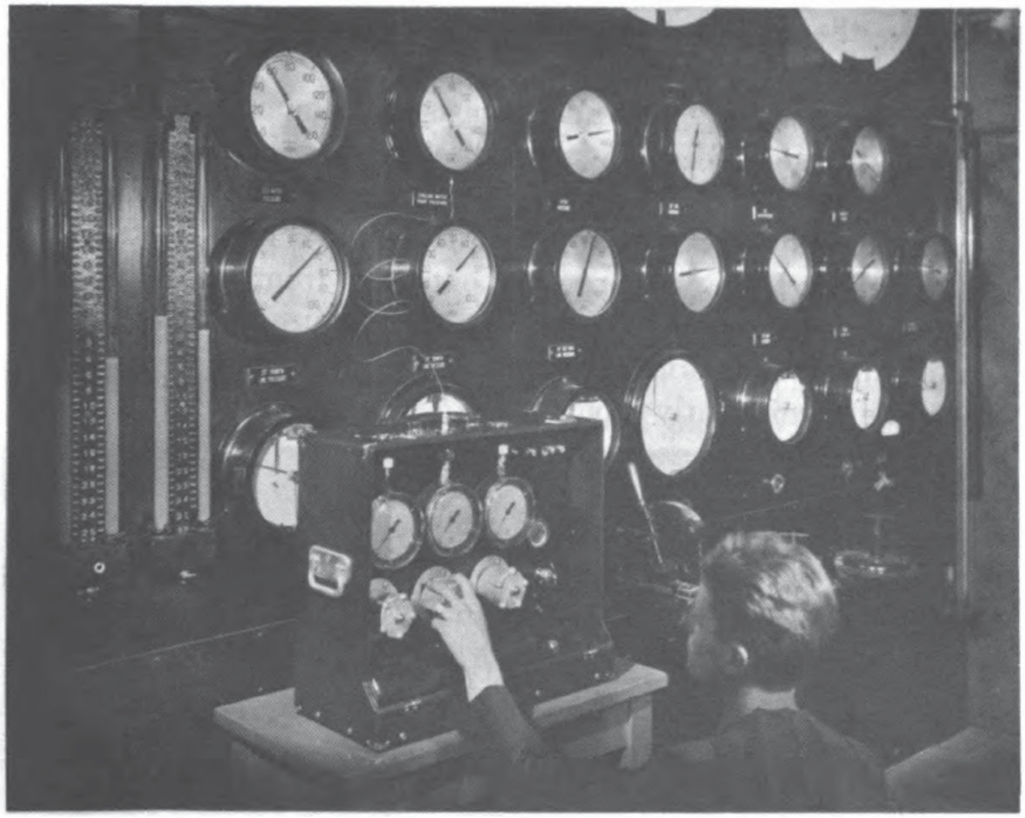


Figure 255. — Operating the portable pneumatic gage comparator.

the self-contained type of tester, to keep the oil in and the dirt out, close the cylinder with the screw cap provided. Close the cock in the gage line. Clean and stow the plunger, weights, and tester in their box. With certain makes of testers the oil must be removed before stowing the tester away.

*Comparator.* — For checking the accuracy of pressure gages in service without removing them from their mountings, the self-contained, portable, pneumatic gage comparator is available. This type of tester is especially valuable whenever there is any possibility of a gage having been damaged by excessive pressure, sudden pressure release, extreme, vibration, or shock of any sort.

The comparator, as its name indicates, is a comparison-type tester. The test is made by comparing the service gage reading with a test gage reading, when both are subjected to the same pressure. The instrument consists of three different range test units, with individual connections for attaching the proper test

gage to the corresponding range service gage to be checked. (See figure 255.)

Each of the range test units consists of a manually operated loader (pressure reducing valve) directly connected to a laboratory test gage, which is accurate to within one-fourth of 1 percent of the maximum reading to which the scale is graduated. The necessary testing pressures are supplied from built-in high-capacity rechargeable gas cylinders. (See figure 256.) Although the comparator is primarily designed as a portable gage tester, it can be permanently mounted.

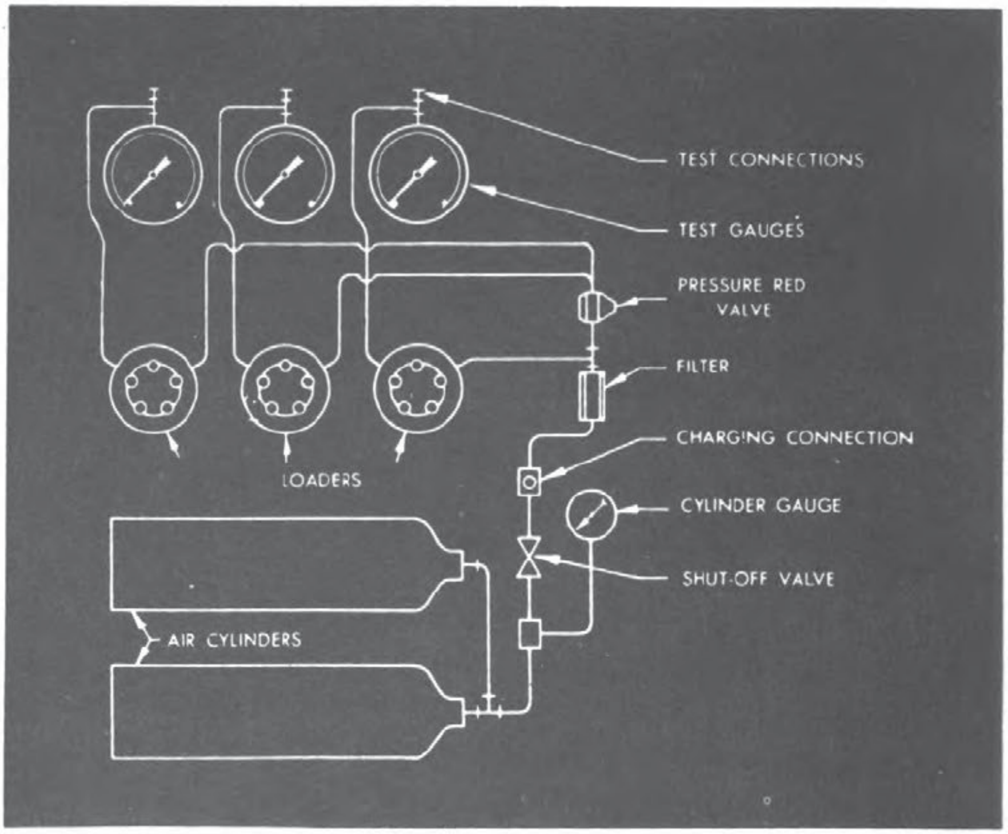



**Figure 256. — Connection diagram — testing three pressure gages with comparator.**

The service gage to be tested is connected, by means of tubing assemblies mounted on the inside of the door and adapters kept at the base of the panel, to the proper test-gage outlet on the top of the comparator. In selecting the correct outlet, choose the one leading to the test gage having the nearest over-all

range corresponding to that of the service gages. Spare or unmounted gages may be screwed directly into the proper outlet connection. Mounted gages should be equipped with a permanently installed plugged tee on the gage, and a cock or valve isolating the gage from the line pressure, in order to simplify checking and obtain the maximum benefits from the comparator.

After the service gage is connected to the comparator, it can be quickly checked by opening the test pressure shut-off valve and turning the handwheel on the loader to the right until the desired pressure is indicated on the test gage. When the gages do not agree, the service gage can be recalibrated in the previously described manner. Rotating the loader handwheel to the left reduces the test pressure. The pressure indicated on the test gage should be reduced to zero before disconnecting the tubing; otherwise the pressure supply will be wasted and the test gage may be subjected to damage caused by a sudden pressure release. The cylinder shut-off valve should likewise be closed at the completion of each test. This will not affect the reading on the small gage which indicates cylinder pressures at all times.

*Test procedure.* — In testing gages with the comparator, you *must* follow the procedure outlined below:

(*a*). Close the valve or cock on the gage to be tested.

(*b*). Connect the service tubing from tee or valve on the service gage to the test connection at top of case above the test gage having the desired pressure range. Unmounted gages may be screwed directly into the connection at the top of the case.

> CAUTION: — ALWAYS CHECK AND BE ABSOLUTELY SURE that the tee, valve, or other service connection to be used in these gage testing operations is designed for high pressure work and will withstand the test pressures with safety.*

(*c*). Make sure all the loader handwheels are turned counterclockwise as far as possible.

(*d*). Open the shut-off valve. This will admit pressure to the loaders.

*The thoughtless use of ordinary thin-wall low-pressure, inadequate tubing connectors for testing pressure gages has caused serious accidents in the past.

(*e*). Now turn slowly clockwise the handwheel of the loader directly under the test gage being used. The test gage will show the loader-delivered pressure, and the service gage, if it is correct, will indicate *the same pressure*. The gage may be checked at as many points as desired until full scale is reached, and rechecked as the pressure is reduced to zero. To obtain maximum service from the air charge (especially if a large number of gages is being tested) high-pressure gages should be checked first, checking low-pressure gages with the remainder of the charge.

(*f*). Before disconnecting the tubing, reduce the pressure to zero by turning the loader handwheel counterclockwise as far as possible.

(*g*). Close the shut-off valve to conserve the charge when the gage comparator is not in use. Approximately one-quarter of a turn is required to open or close the shut-off valve.

*Recharging cylinders.* — A high-pressure source of clean, dry gas or air is required for recharging the pressure cylinders when their supply becomes exhausted. To charge a cylinder, the cylinder valve should first be closed, then the charging plug removed and the service tubing connected from the charging source. If the pressure source is less than 2,500 p.s.i., charging will be rather slow due to the small size of the tubing. By opening the cylinder valve, the cylinder can be charged not to exceed 2,000 p.s.i. When this pressure is reached in each of the cylinders, close the cylinder valve and replace the charging plug. The comparator is then ready for further use.

*Care and maintenance.* — The comparator, while rugged, is a precision instrument and should be handled as such. If shock or vibrations are unavoidable either in transit or in storage, unscrew the plastic gage covers and snub the hands with wisps of absorbent cotton. To avoid damage from sudden pressure release, never disconnect the tubing until the loader pressure has been returned to zero. Test gages should be periodically checked against a deadweight tester. No error will be introduced by mounting gages upside down on the deadweight tester.

*Fluid pressure scales.* — The fluid pressure tester (see figure 257) is useful for testing the high-pressure gages when the

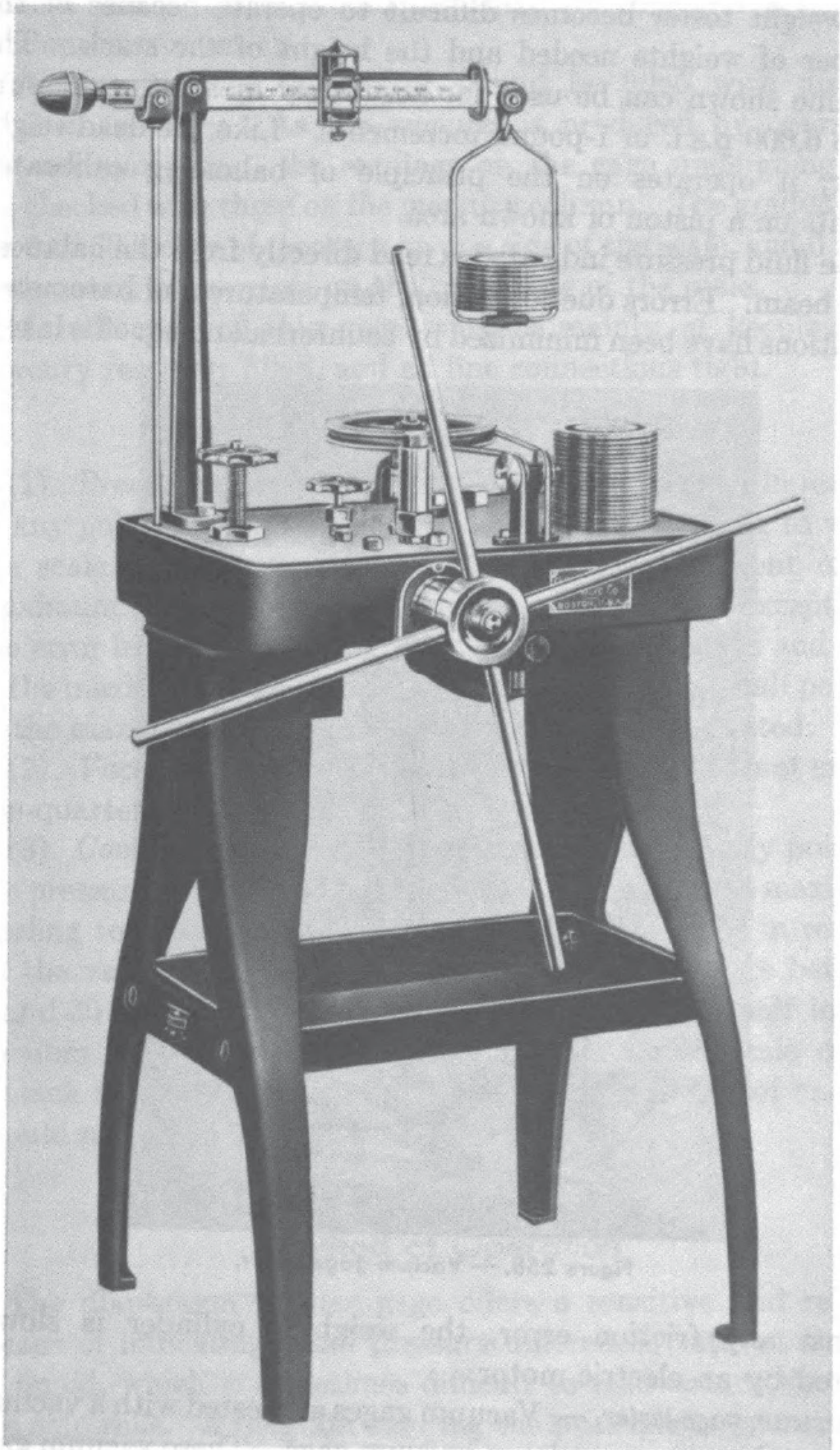


Figure 257. — Fluid pressure scales.

deadweight tester becomes difficult to operate because of the number of weights needed and the height of the stack. The machine shown can be used for accurately measuring pressure up to 6,000 p.s.i. in 1-pound increments. Like the deadweight tester, it operates on the principle of balancing calibrated weights on a piston of known area.

The fluid pressure indicated is read directly from the balanced scale beam. Errors due to friction, temperature and barometric conditions have been minimized by counterbalancing. To insure

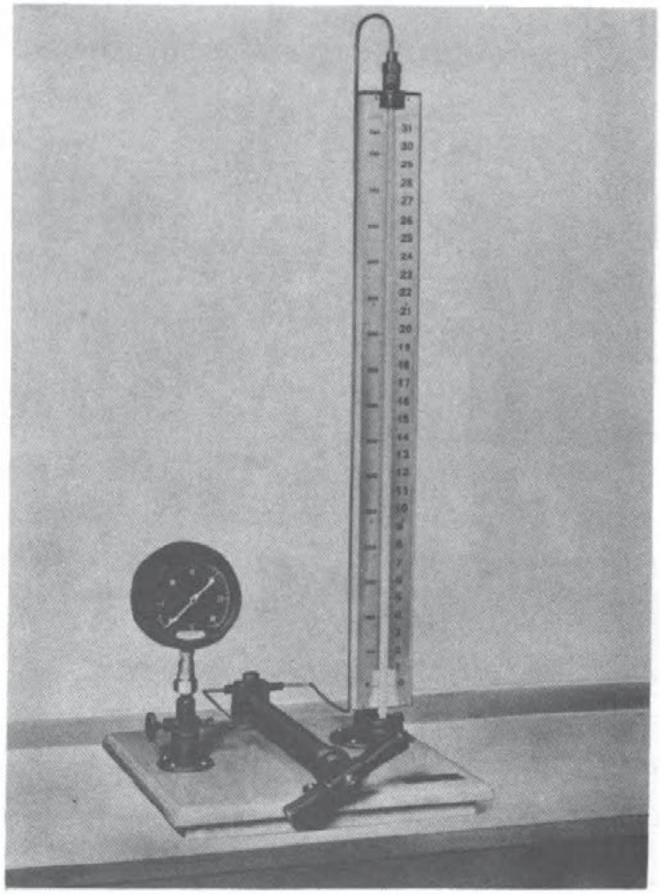


Figure 258. — Vacuum gage tester.

against any friction error, the weighing cylinder is slowly rotated by an electric motor.

*Vacuum gage tester.* — Vacuum gages are tested with a vacuum pump and a mercury column vacuum gage. These vacuum gage testers, one of which is shown in figure 258, are accurate and easy to operate. Since a perfect vacuum cannot be created by

a hand pump, gages should be tested up to about a 28-inch vacuum maximum.

The reservoir of this tester should be filled with double-distilled mercury. As the vacuum is produced by operating the vacuum pump, the readings on the gage undergoing test are checked with those on the mercury column. The graduations are 0 to 30 inches of mercury on one side of the scale, and 0 to 76 centimeters of mercury on the other side of the scale.

Maintenance of this gage consists mainly of keeping the mercury reservoir filled, and all line connections tight.

## ALLOWABLE GAGE ERROR

(1). *Pressure gages.* — The maximum allowed error in reading at any point above 5 percent of the maximum reading to which the scale is graduated should not exceed 1½ percent of the maximum reading to which the scale is graduated; except that the error in reading over the gradations between 33⅓ and 66⅔ of the maximum scale reading should not exceed one-half percent of the maximum reading to which the scale is graduated.

(2). *Vacuum gages.* — The error in reading should not exceed one-quarter inch vacuum between 5 and 30 inches.

(3). *Compound gages.* — The error in reading at any point on the pressure scale should not exceed 1½ percent of the maximum reading to which the scale is graduated. The error in reading on the vacuum scale of the 30-inch to 30-pound gage between 5 and 30 inches of vacuum should not exceed one-half inch of vacuum. The error in reading on the vacuum scale of the 30-inch to 100-pound gage between 5 and 30 inches of vacuum should not exceed 1½ inches of vacuum.

## DIAPHRAGM GAGES

### Method of Operation

The diaphragm pointer gage offers a sensitive and reliable means of indicating small pressure differences without the use of liquid, which is sometimes difficult to read accurately when the ship rolls. A diagram showing the principle of operation of a vertical-dial air-pressure diaphragm gage is shown in figure 259. These gages are usually specially designed for the service

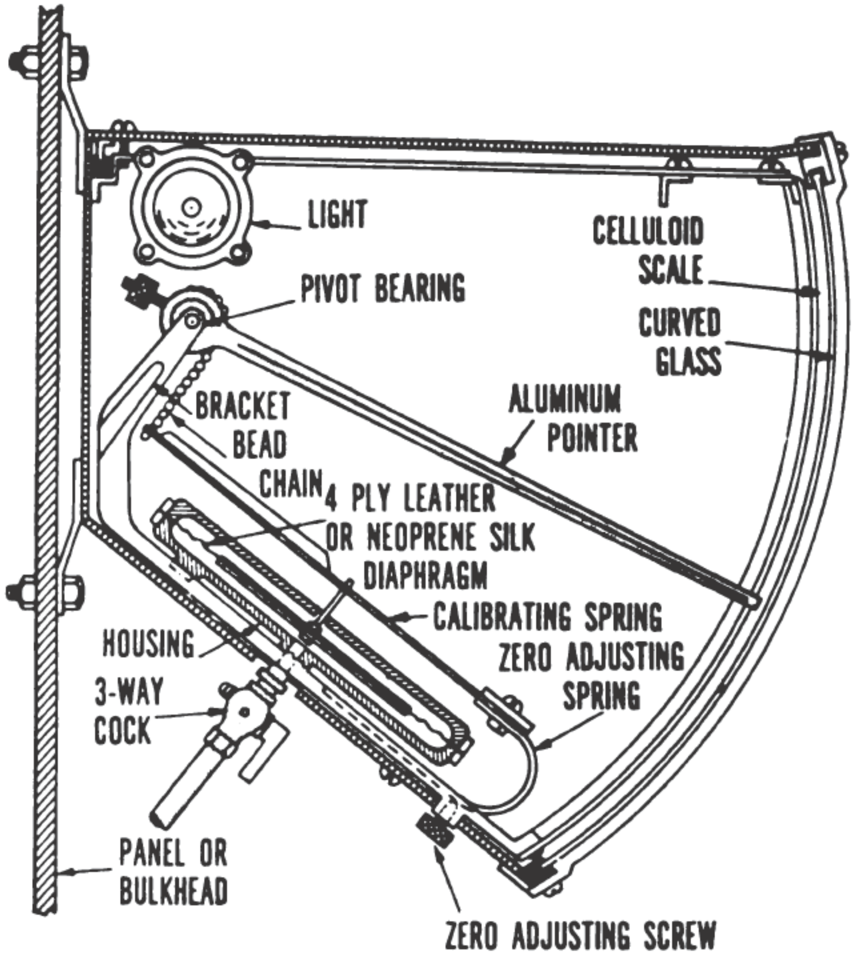



Figure 259. — Details of diaphragm air-pressure gage.

desired, then calibrated or recalibrated at the time of installation.

The operating mechanism of this type of gage consists of a slack leather diaphragm and a phosphor-bronze spring attached to a pointer mounted on a pivot bearing. The diaphragm is a pliable, tough, airtight membrane. It transmits the force of the air pressure to the counterweighted pointer, and produces a reading on the scale in direct proportion to that force. The spring is of the cantilever (projecting beam) type, and is harnessed to the pointer by a strong non-kinkable bead chain. The large area of the diaphragm insures a high degree of sensitivity which is transmitted directly to the scale.

Sometimes two internal diaphragm units with separate points are installed in a single case and calibrated to show comparative

pressures. A gage of this type, commonly used for comparing the pressures in the boiler smokepipe and in the furnace, is shown in figure 260.

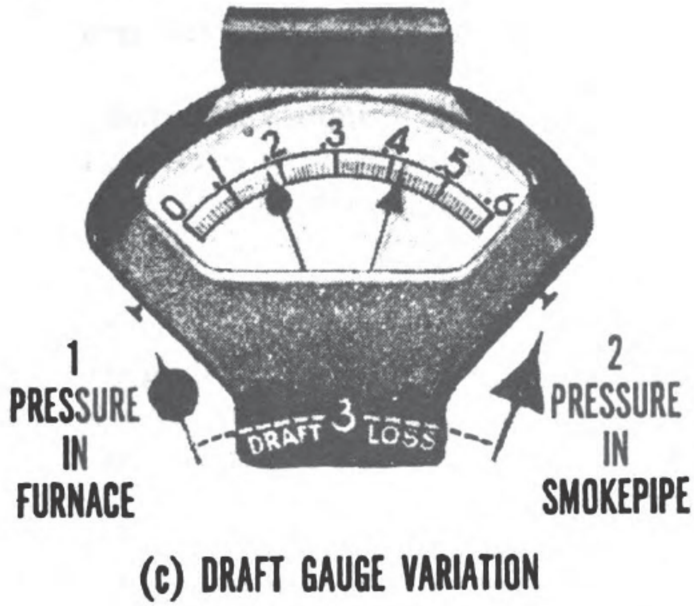



Figure 260. — Diaphragm-type duplex draft gage for checking pressures in furnace and smokepipe.

## Zero Adjustment

A three-way pressure cock is provided for each unit. This makes it possible to shut off the gage and check the zero reading without disconnecting the piping at the instrument. When the handle of the three-way cock is at right angles to the valve body, the gage unit to which the cock is connected is open to room pressure. When this handle is parallel to the valve body, the unit is in service. Units should be checked weekly by turning the cock handle at right angles to the valve body.

If it becomes necessary to reset the pointer at zero on the scale, use the zero adjusting screw just below the unit (see figure 261). Screw in or out, as required, to bring the pointer to zero. Then turn the cock handle parallel to the valve body, and the gage is in service.

## Maintenance

The diaphragms used in this type of gage are of the replaceable

type. They are designed to give years of trouble-free service, but occasionally through mistreatment or accident they must be replaced. To replace a diaphragm, first disconnect the pressure line below the unit, remove the outside zero adjustment screw and three-way cock with its coupling, and remove the unit from its case.

In disassembling the unit, compress the small spring on top of the calibrating spring, to loosen its retaining pin. Remove the stem which holds the calibrating spring, and the 10 screws around the edge of the casting. The old diaphragm can then be lifted out.

Clean both surfaces of the casting, apply a small amount of gasket cement to the edge of the lowest casting and immediately place the new diaphragm-gasket assembly over the lower casting's edge. Replace the top casting; tighten the screws, being careful to draw them up uniformly so as to provide a tight joint. Replace the calibrating spring stem, compress the spring and insert its pin in the stem. Replace the unit in the case, and the gage is ready for service.

## MANOMETERS

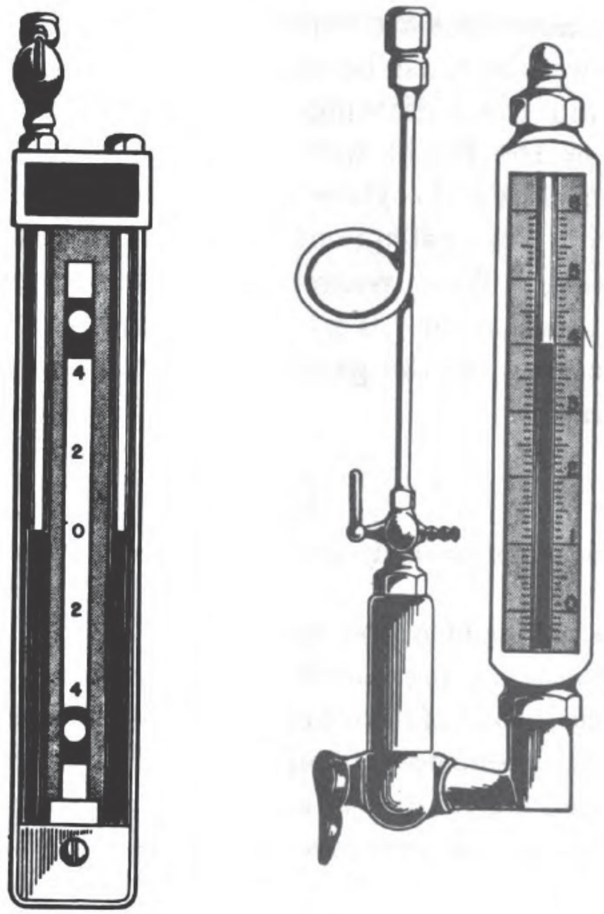
For measuring low pressure such as fireroom pressures, and small pressure differences or *drafts*, the liquid manometer is used. Pressures up to 15 p.s.i. above and below that of the atmosphere can be measured with this kind of gage. The operating principle of manometers is fully explained in chapter 9 of Basic Machines, NavPers 10624.

These instruments are made in a wide range of sizes and types. The liquids commonly used as the registering fluid are water, oil, and mercury, the latter being employed when unusually high pressures are to be measured. Readings are usually in inches of water.

### Method of Operation

A conventional form of manometer is shown in figure 261A. It consists of a one-piece pyrex glass indicating U-tube mounted on a metal base. An adjustable scale is located between the legs of the U-tube. One side of the U-tube is connected to the source of pressure to be measured, the other side to the atmos-

phere. The difference between the heights of the liquid columns is plainly visible. This difference of pressure is usually read in inches of water as stated above, but may be calibrated to read directly in units of pressure if desired. The single-tube manometer shown in figure 261*B* functions in the same way as the U-tube manometer, the main difference being that only one leg of the U-bend is made of glass.




A B

**Figure 261. — (A.) Standard U-tube manometer. (B.) Single-tube manometer.**

Special forms of manometers embody the same general principle as the ordinary U-tube type. Some types used in measuring unusually high pressures are filled with mercury. For conversion purposes, 1 inch of mercury equals 13.61 inches of water, and 1 inch of water equals 0.0735 inches of mercury.

## Maintenance

Beyond an occasional replacement of a broken glass tube, no maintenance problems are to be expected with liquid manometers. The amount of liquid in them should be such that when both sides are exposed to normal atmospheric pressure, the levels of the liquid will be at the zero mark. When the liquid used is other than water, do not permit moisture to accumulate inside the tube. Keep the tube free from dirt and dust, and see that all connections are very tight.

When a new tube must be installed in a single-tube manometer, first drain the indicating liquid by opening the plug in the bottom of the liquid well, and then remove the excess-pressure trap above the glass tube. Loosen the gage frame, remove it from the instrument, and replace the broken tube with a new tube. When reassembling, use new gaskets and be sure all joints are tight. Test the tube unit for leaks, and if found satisfactory fill the gage with new indicating fluid and place it in service.

## QUIZ

1. What sizes of pressure and vacuum gages are commonly used on naval vessels?
2. How does the Bourdon gage operate?
3. For what pressure ranges are Bourdon gages used?
4. What is the purpose of the red extra hand used in all Navy dial gages?
5. How much pressure does atmosphere exert?
6. What reading is given on most gages to indicate atmospheric pressure?
7. What is the relation between force and pressure?
8. How would you change a gage reading of atmospheric pressure to absolute pressure?
9. How does the compound Bourdon gage operate?
10. What is a hydraulic Bourdon gage?
11. What is a duplex Bourdon gage?
12. How does a differential pressure gage operate?
13. What four conditions requiring adjustment occur most commonly in Bourdon gages?
14. How would you repair a Bourdon gage whose pointer shows a sticky or sluggish action at certain points?

15. How would you repair a much-used Bourdon gage whose motion for a given pressure is more or less than it was originally?
16. If you received a 6-inch metal case pressure gage for repair, and you learned that it is normally installed in a location subject to corrosive fumes, what action would you take?
17. What is the principle of operation of a diaphragm gage?
18. What is the particular advantage of the diaphragm gage?
19. For what purpose are manometers used?
20. What is the usual pressure range for manometers?
21. How often should pressure gage movements, or linkages, be oiled, and why?
22. How often should pressure gages be tested?
23. What is the particular advantage of the pneumatic gage comparator?
24. The principle parts of the pneumatic gage comparator are: the loaders, the air cylinders, the test pressure shut off valve, the test connections, the air cylinder gage, the pressure reducing valve and the filter. Make a drawing of the diagram shown in figure 256 and label these parts. (Do not write in the book.)
25. How does a hydraulic deadweight gage tester operate?

# CHAPTER 14

# THERMOMETERS, PYROMETERS, AND COMBUSTION CONTROL INSTRUMENTS

## THREE CLASSES

The temperature measuring instruments used in the Navy may be divided into three classes: (1) liquid-in-glass thermometers, (2) distant-reading indicating dial thermometers, and (3) pyrometers. The accompanying table shows the range for the different Navy temperature measuring devices.

| *Type* | *Range in Degrees F.* |
|---|---|
| 1. Liquid-in-glass thermometer | − 35 to 750 |
| 2. Distant reading thermometer: | |
| a. Liquid-filled (mercury) | − 38 to 1000 |
| b. Vapor-pressure | − 20 to 700 |
| c. Gas-filled | − 60 to 3000 |
| 3. Thermocouple pyrometer | 300 to 2000 |

## Liquid-in-Glass Thermometers

Since mercury is widely used in the various temperature measuring instruments, we will first study some of the characteristics of that substance. Because of the small amount of expansion of mercury, it is necessary, when using it in a thermometer, to employ capillary tubing having a very small bore. This small-bore tubing, taken in conjunction with the high surface tension of the mercury, introduces slight errors into the readings. However, these errors are fairly regular and are compensated for in the design of the glass tube. More serious, especially at high temperatures, is the imperfect elasticity of the glass itself, which causes irregular changes in the volume of the tube. This adds greatly to the general inaccuracy of this type of thermometer and as a result, liquid-in-glass thermometers are not employed in obtaining precise measurements of high temperatures.

The chief advantages of mercury, from a standpoint of temperature measurement, are its high boiling point, its low freezing point, its almost total lack of evaporation at the temperatures for which it is used, and its nonadherence (when chemically pure) to the inside walls of the stem. Its high conductivity makes it quick and sensitive in its action, and because it is opaque, it permits accurate scale readings.

The liquid-in-glass thermometer (figure 262) depends for its operation upon the expansion of the liquid mercury sealed in a glass bulb attached to one end of a thin, graduated tube or stem which is closed at the other end. The bulb and a portion of the stem are filled with mercury, and the rest of the stem is filled with its vapor. A small amount of an inert gas is generally introduced into the stem so as to minimize vaporization of the liquid. Temperature readings are taken by noting the position of the meniscus (curved upper surface) of the liquid in the stem when the bulb is in contact with the medium whose temperature is to be measured.

This type of thermometer is made in armored and unarmored types, and in straight stem, angle, and oblique types. In some

types, a metal casing with a scale surrounds the glass tube and the stem. The commonly used angle stem types are shown in figure 263. Besides mercury, such liquids as alcohol, benzene, and toluene are sometimes used. In figure 264 the man on watch is shown reading the *lube*-oil temperatures on the reduction gear casing.

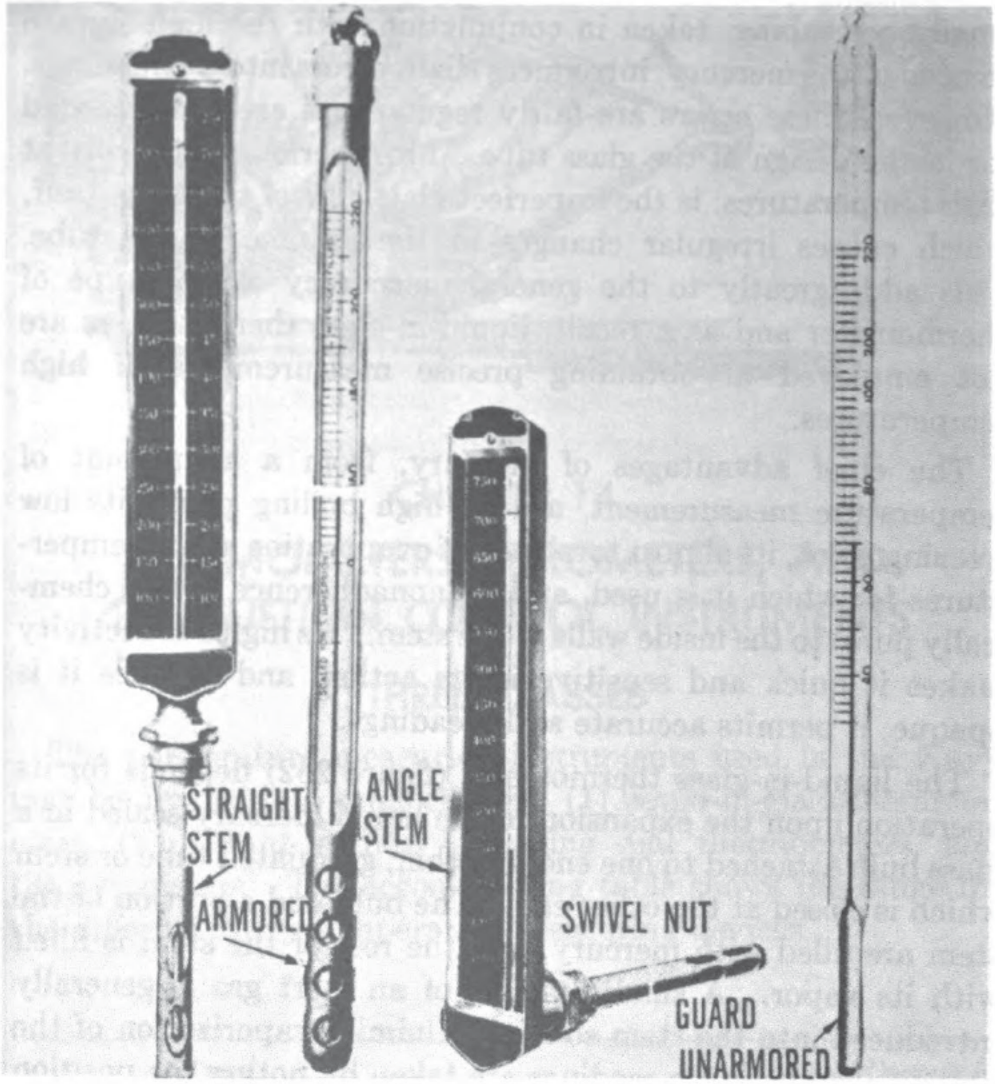



Figure 262. — Types of liquid-in-glass thermometers.

A standard industrial thermometer, with 9-inch stem, made especially for the Navy, is used for all services generally. In taking readings where space is limited, however, such as taking brine temperatures in ice machines, lubricating oil and bearing temperatures, air compressor discharge air temperatures and

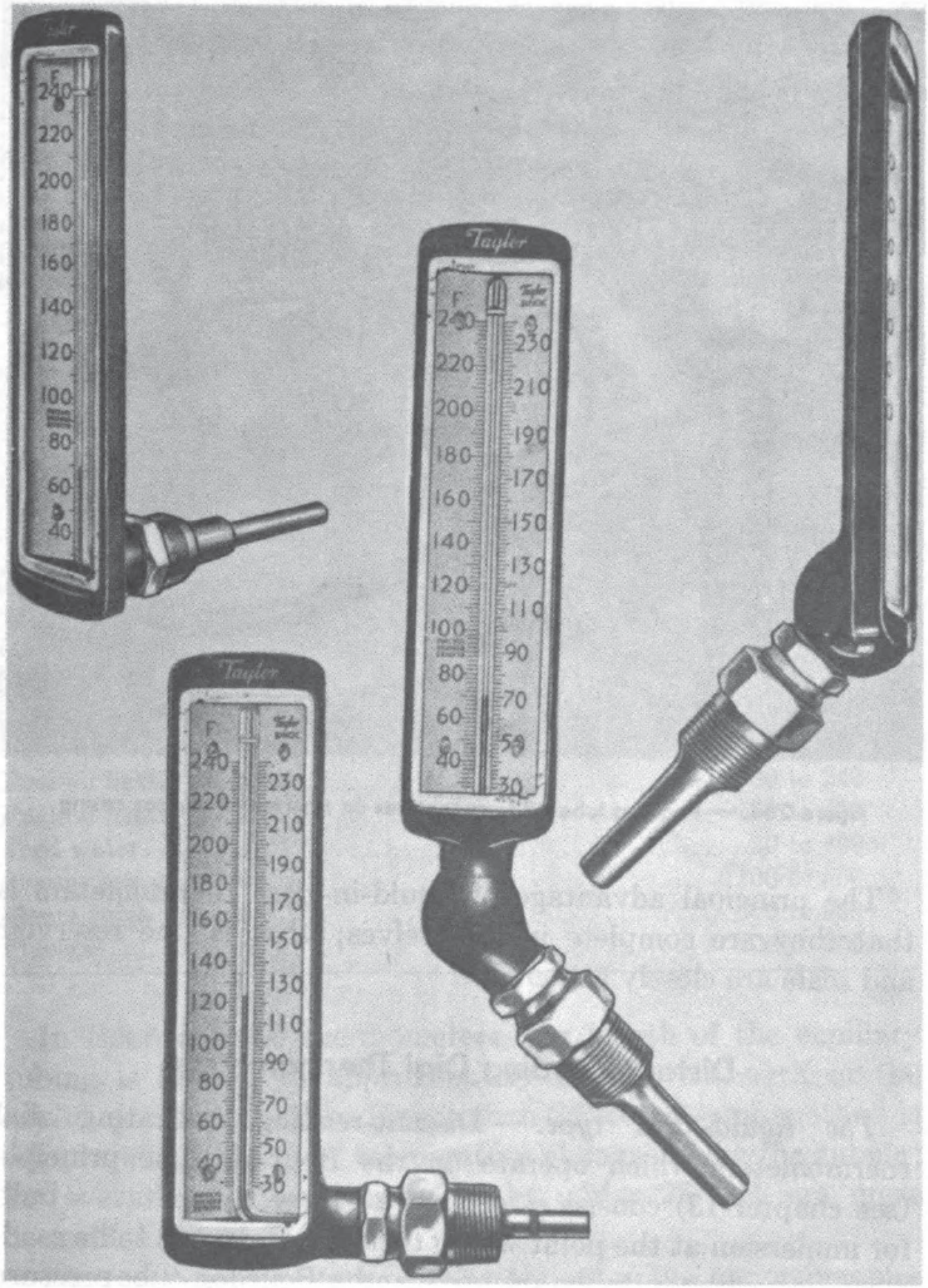



Figure 263. — Angle stem types of thermometers.

all water and fuel-oil temperatures, the special five-inch stem thermometer should be used. Separable socket fittings are commonly used to hold these thermometers.

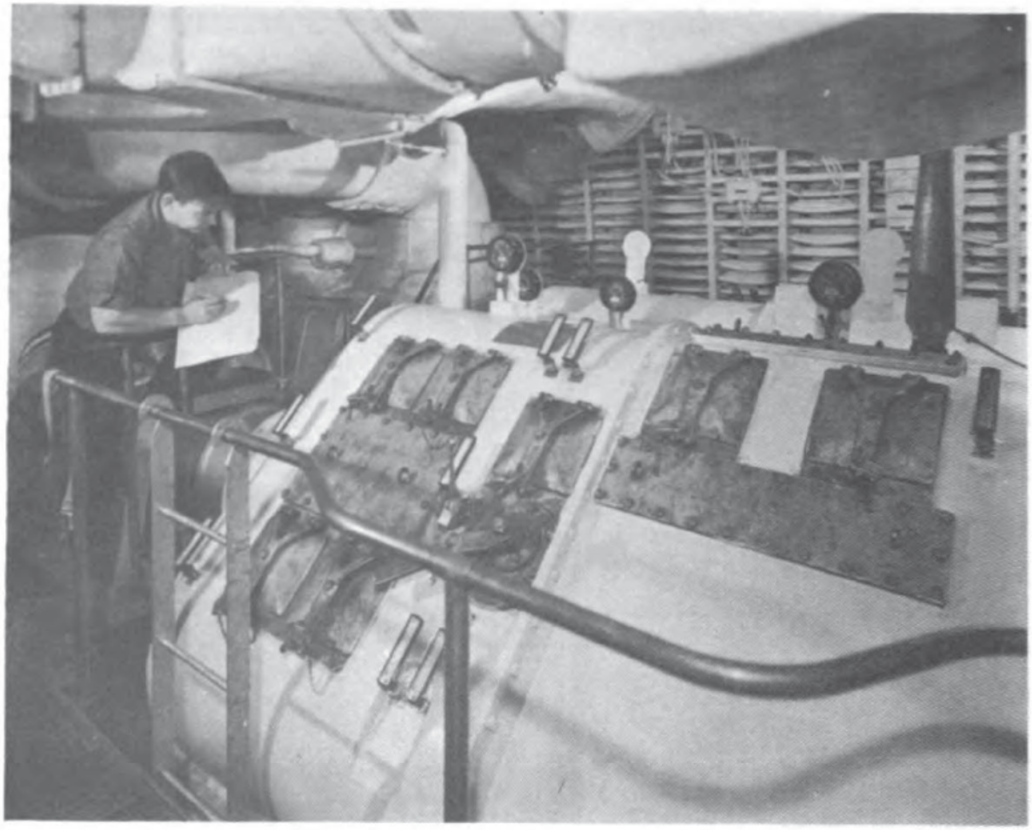


Figure 264. — Reading lube-oil temperatures on the reduction gear casing.

The principal advantage of liquid-in-glass thermometers is that they are complete in themselves; that is, the reservoir and scale are closely attached.

## Distant-Reading Dial Thermometers

*The liquid-filled type.* — Distant-reading indicating dial thermometers which operate on the Bourdon-type principle (see chapter 13) consist essentially of three elements: a bulb for immersion at the point where the temperature is to be read, a capillary tube suitably armored, and a Bourdon-tube pressure gage. An instrument of this type is shown in figure 265. Under present specifications, all distant-reading thermometers made for Navy use have the three elements filled with mercury. Expansion of the mercury within the bulb imparts to the gage a pressure proportional to the temperature at the bulb. The scale is graduated to read directly in degrees of temperature.

If this thermometer is to provide an accurate reading, the bulb must be so located that it will acquire and maintain the temperature of the material to be tested. The bulb in any of these thermometers should always be used in the special socket furnished. The space between the socket and the bulb is filled with heavy mineral oil and finely powdered graphite, so as to decrease the excessive time lag to which this type of thermometer is subject.

Distant-reading dial thermometers are used in the Navy in the following locations:

| *Location* | *Range, In Degrees F.* |
|---|---|
| Refrigerating lines and refrigerator rooms | − 40 to 110 |
| Overhead discharge | 30 to 240 |
| Main injection | 30 to 180 |
| Condenser shell | 30 to 240 |
| Bearings | 30 to 240 |
| Lube-oil cooler — oil | 30 to 180 |
| Lube-oil cooler — water | 30 to 240 |
| Fuel-oil heater oil inlet | 30 to 240 |
| Fuel-oil heater oil outlet | 50 to 400 |
| Feed water | 50 to 400 |
| Steam (low pressure) | 100 to 550 |
| Steam (high pressure) | 400 to 850 |
| Flue gas | 200 to 950 |

In Bourdon-tube thermometers, the length of the capillary tubing is limited to approximately 25 feet. Length of the capillary tubing may be longer than 25 feet if some method is used to compensate for temperature changes along the tubing; however, installations with lengths under 25 feet are more desirable.

*The vapor-pressure type.* — The action of the vapor-pressure thermometer depends upon the fact that the pressure inside the tubing is determined by the temperature of the free surface of the liquid. If the capillary tubing and the Bourdon tube contain vapor, the indications are not subject to error resulting from a variation of the temperature in the tubing and pressure spring.

The liquids most commonly used in vapor-pressure thermometers are water, alcohol, benzene, tuolene, aniline, sulphur oxide, and ether.

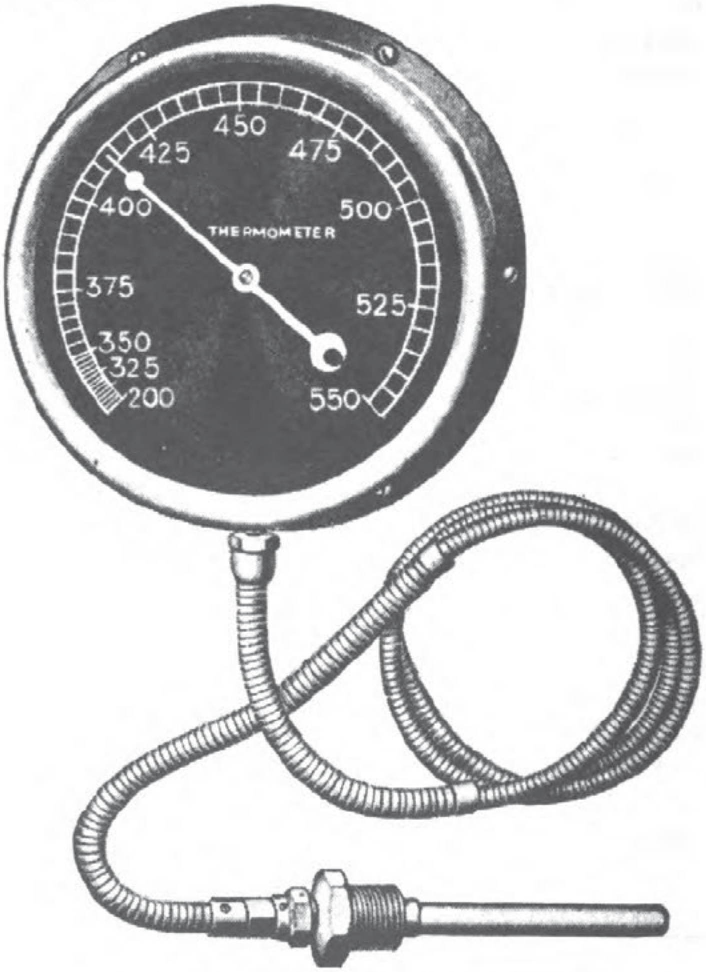



Figure 265. — Distant-reading thermometer.

The main advantages of this type of thermomete. ·e that, when property installed, it is subject to a minimum error resulting from temperature variations of the capillary tubing, and that any length of tubing up to 200 feet may be used. Its chief disadvantages are that its readings vary in accuracy with the fluctuations of barometer pressure, and vary also when the bulb is elevated or lowered any considerable distance with relation to the position of the dial.

*The gas-filled type.* — The gas-filled thermometer is similar to the liquid-filled type, except for the size of the capillary tubing.

The gas most commonly used is nitrogen. The chief advantage of this type of thermometer is that there is no restriction on the length of capillary tubing. The principal disadvantage is that it is subject to error if the capillary tubing when in service is used at a different temperature from that employed in its calibration.

## General Construction

The bulbs of Bourdon-tube thermometers may vary in size, shape and material, depending upon the application. The materials most frequently used for bulbs are glass, steel, bronze, copper, monel metal and brass. The capillary tubing used in the Bourdon-tube thermometer is generally made of steel, bronze, copper or lead-covered steel. It is sometimes strengthened by a flexible armor. All connections in this tubing should be soldered or welded.

## Maintenance

A thermometer that appears to be recording inaccurately should be tested at the freezing and boiling points, comparisons being made with other thermometers known to be accurate. A solution at 32° Fahernheit (which is equivalent to 0° Centigrade) can be made with pure ice and distilled water. Break the ice into small pieces, mix it with a small amount of water, and stir the mixture thoroughly for several minutes to obtain this freezing temperature.

Errors in Bourdon-type thermometers are corrected by the same methods used for correcting other pressure tube gages. The adjustment and maintenance of these gages was discussed in chapter 13, Any loss of mercury can be replaced only by the manufacturer; great care must therefore be taken to prevent damage to the Bourdon tubes, and especially to the capillary tubes. Variations of temperature between tubing and dial will cause slight errors of recording, so such variations should be kept to a minimum. Extra tubing should be neatly coiled and clamped to a support.

Always handle thermometers carefully, especially those of

the engraved type, as they are easily broken. If the mercury becomes separated, do not try to bring the parts together by tapping or jarring the thermometer. Hold it by the upper end and make several full-arm swings, to correct the trouble. If this method does not succeed, heat the bulb carefully until the rising temperature brings the two parts of the mercury together.

Bare-bulb thermometers (i.e., the type in which the bulb is in direct contact with the superheated steam) should not be removed for replacement or servicing while the boiler is steaming under pressure.

Broken glass faces of fixed dial-reading thermometers should be replaced promptly, in order to protect the tube and to prevent corrosion of the graduated scale.

## Pyrometers

Where a large number of temperatures must be read at a distant point, electrical temperature indicating instruments such as pyrometers and indicating resistance thermometers, are employed. Pyrometers are often installed in the base of the boiler stack to obtain stack temperatures, from which the boiler's efficiency is computed. Determination of a Diesel engine's cylinder and combined exhaust temperatures, and the temperature of the windings in the electrical machinery, are also common applications for this kind of equipment.

The pyrometer is the accepted instrument in scientific research for determining high temperatures. It is widely used for the same purpose in engineering plants. Since it excels the simple mercurial thermometer in range, sensitivity and adaptability, it can be used for many purposes where an ordinary thermometer would be useless. It is a very sensitive instrument, however, and must be handled carefully. You may be called upon to repair the dials of these instruments, or to replace screws shaken out by rough handling, so you should be familiar with Navy pyrometers.

## The Principle

A thermoelectric pyrometer of the type employed to indicate boiler uptake temperatures is shown in figure 266. It is known

that if two dissimilar metals, such as iron and constantin or chromel and alumel, are joined at one end and heated at that junction (called a thermocouple), an electromotive, or electric

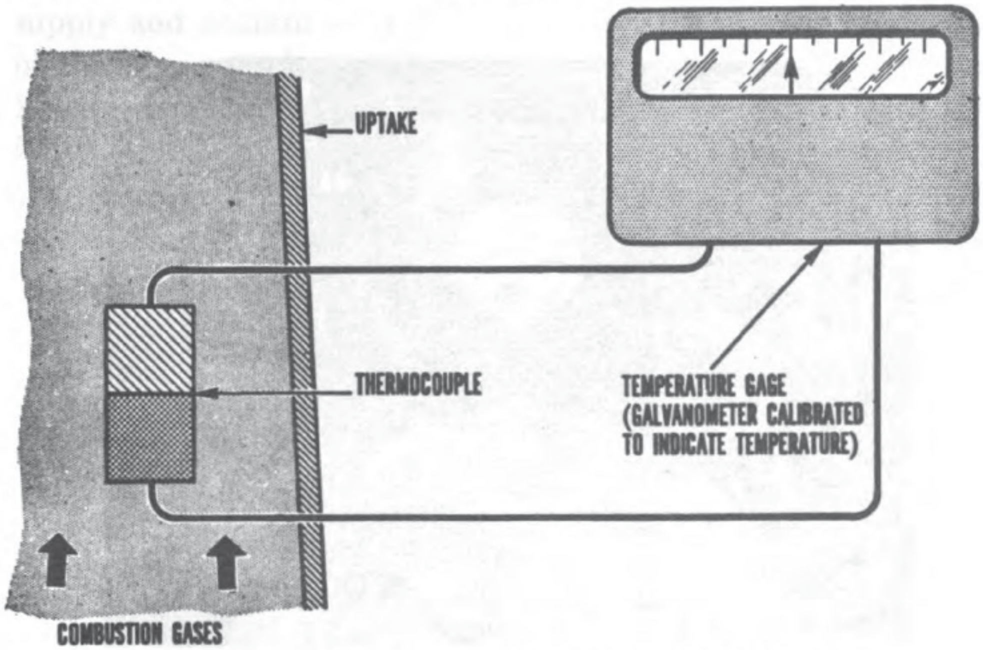



Figure 266. — Diagram showing pyrometer principle.

current-producing force will flow through the circuit formed by connecting the other two ends. The higher the temperature that is being measured, the greater the electromotive force that will be created. A sensitive high-resistance galvanometer, a delicate current-indicating instrument, is installed in the circuit to measure the current generated by the temperature change at the thermocouple. The dial is calibrated to read directly in degrees Fahrenheit.

Pyrometers are either portable or fixed. The fixed pyrometer is more accurate, so it is used on the larger, more expensive installations.

## Pyrometer Types

The three common types of pyrometers are: (1) the indicating type, for simple temperature indication, (2) the recording type, for continuously recording temperatures, and (3) the controlling type for temperature control. Several or all of these types may be incorporated in a single instrument.

*Indicating type.* — The dial of a standard indicating thermocouple pyrometer is shown in figure 267. The thermocouple is mounted at a point where the temperature reading is desired.

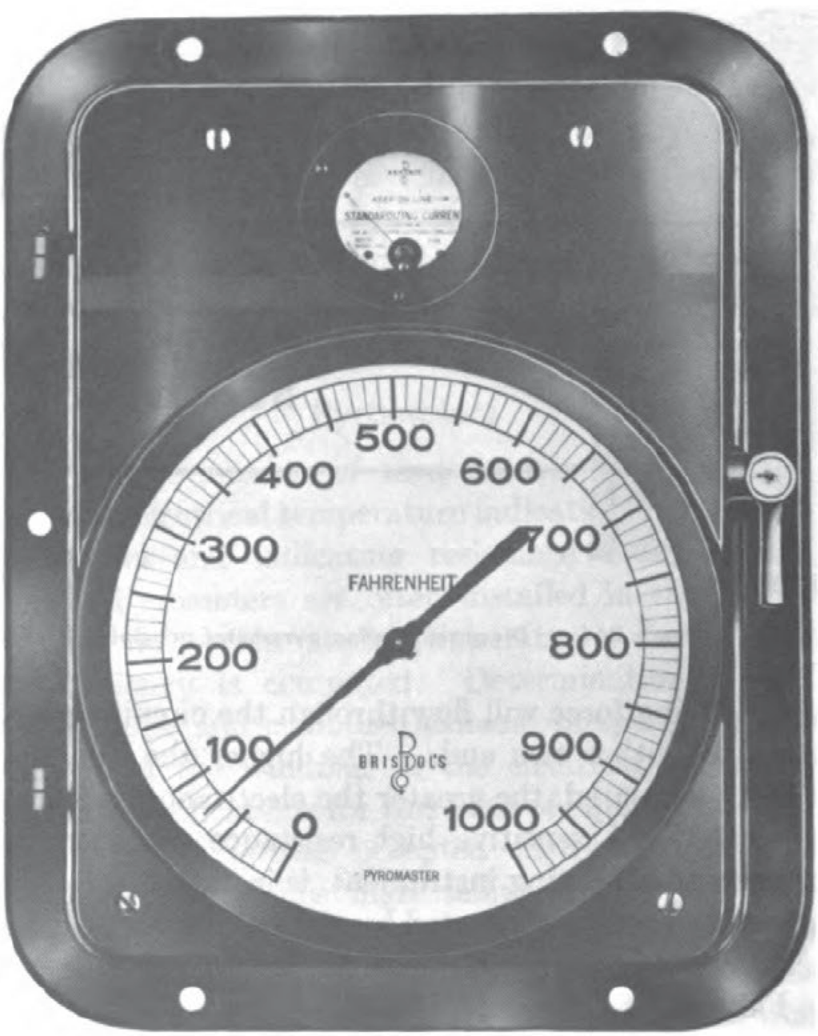



Figure 267. — Thermocouple pyrometer.

Indicating resistance thermometers work on the same principle as the pyrometer, being calibrated to measure the increase in electrical resistance of certain metals with the temperature. The variation of resistance is measured in these instruments by a small wheatstone bridge located inside the dial case; a sensitive galvanometer is calibrated to indicate the temperature on the single dial (figure 268) directly in degrees Fahrenheit. No thermocouple is used with this instrument.

Instructions for operating and maintaining indicating thermocouple pyrometers and indicating resistance thermometers are furnished by the manufacturer with each installation. Since these instruments operate on a 110-volt, 60-cycle power supply and contain a number of electrical subassemblies, most of the repair work on them will be done on shipboard by the Electrician's Mate. You yourself should be familiar with the fundamentals of electricity, though, so as to understand the operating principles of the standard electrical measuring instruments. You can get a lot of this basic knowledge by reading


Figure 268. — Resistance thermometer.

the Navy Training Manuals, *Basic Electricity*, NavPers 10622, and *Electrician's Mate 2*, NavPers 10103, giving special attention to the sections on "Induction" and "Electrical Meters."

*Recording type.* — Recording thermometers, which give a graphic record of temperature fluctuations over a period of time, are made to be actuated by either a mercury, vapor gas, or liquid tube system. Each system has definite advantages for certain applications and conditions. Mercury, having a uniform coefficient of expansion, permits the use of a chart with uniformly shaped graduations. Records can then be read with equal accuracy over the entire scale. Mercury-actuated recording thermometers are adaptable to short or long operating ranges (up to 200 feet maximum) within their temperature limits, usually from 38° to 100° F. Their small bulbs allow them to be used in limited space, such as in pipe lines. For these reasons the recording thermometers used in the Navy are all of the mercury-actuated type.

Vapor-actuated recording thermometers have an advantage when readings are required at the higher end of their temperature range (0° to 600° F.). The spacing of the degree divisions on their charts gradually increases with rising temperature, to allow for the fact that the pressure of volatile liquids increases at a more rapid rate as the temperature goes up.

Recording thermometers of the gas-actuated type are especially adapted for use on applications requiring long lengths of tubing when the temperature fluctuations around the recorder case and along the connecting tubing are negligible, and where installation space is adequate to accommodate their larger bulbs.

When the application requirements cannot be adequately met by mercury, vapor or gas actuation, a volatile liquid-actuated recording thermometer may be installed. Where a small bulb is required, with a short range and low temperatures (– 125° to 500° F.), this type of instrument will usually give satisfactory service.

A sketch showing the elements of a mercury-actuated recording thermometer is given in figure 269. The four main units are (*A*), the bulb with mercury; (*B*), the flexible stainless steel tubing; (*C*), the special alloy filler wire; (*D*), and the Bourdon spring. The alloy filler wire which extends through the bore of the tubing has a coefficient of expansion so related to that of the tubing and the mercury that expansion or contraction of

tubing or mercury due to variations in temperature is accurately counteracted at the point of fluctuation. A cutaway view showing the interior mechanism of a single pen recording thermometer is shown in figure 270. Slight adjustments to correct for accidental disturbance of calibration are made by turning a

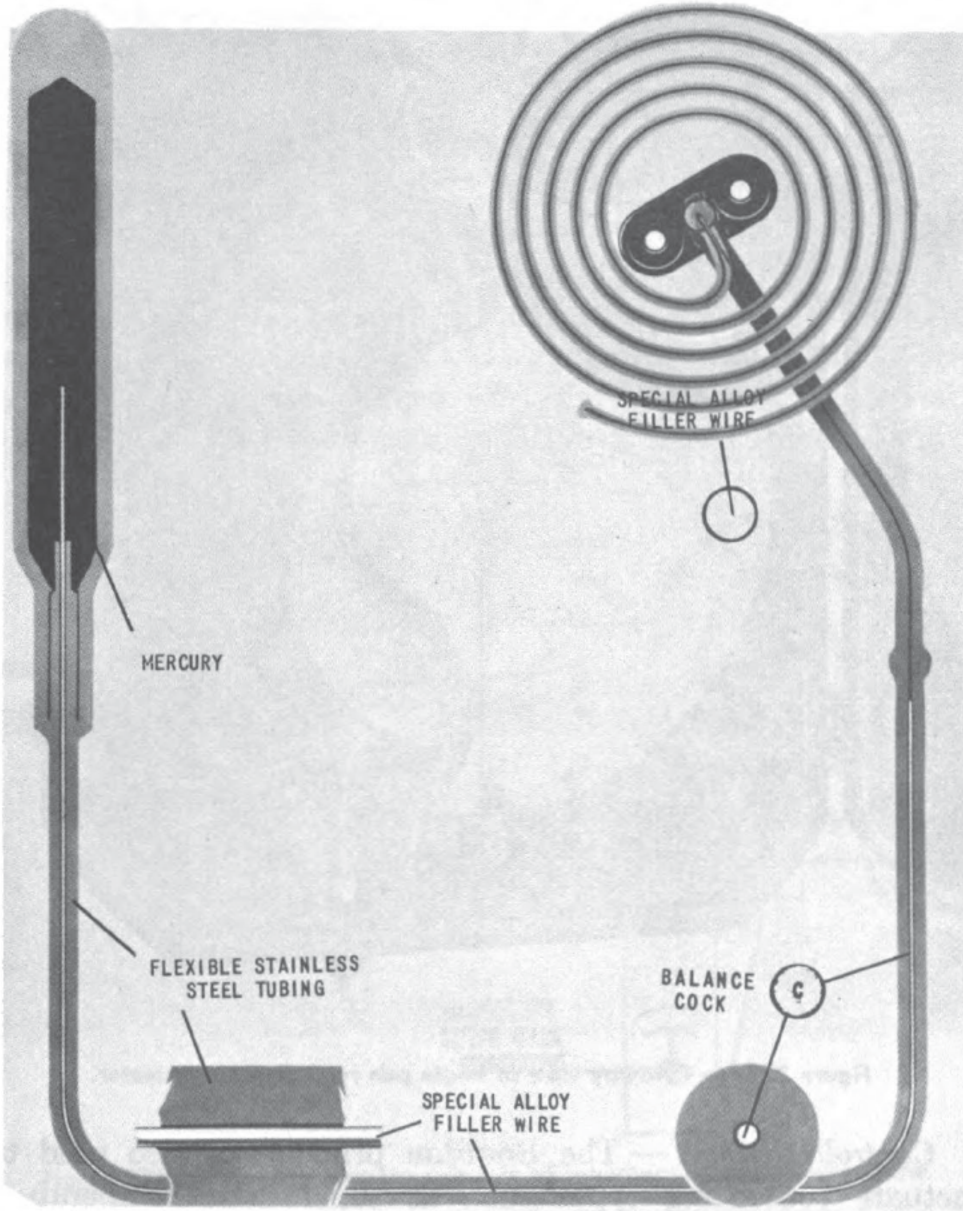



**Figure 269. — Elements of mercury-actuated recording thermometer. A., Mercury. B., Flexible stainless steel tubing. C., Special alloy filler wire. D., Bourdon spring.**

small adjusting screw on the pen arm. A supply of charts, a bottle of ink with filler, and several pens should be kept handy for maintenance purposes.

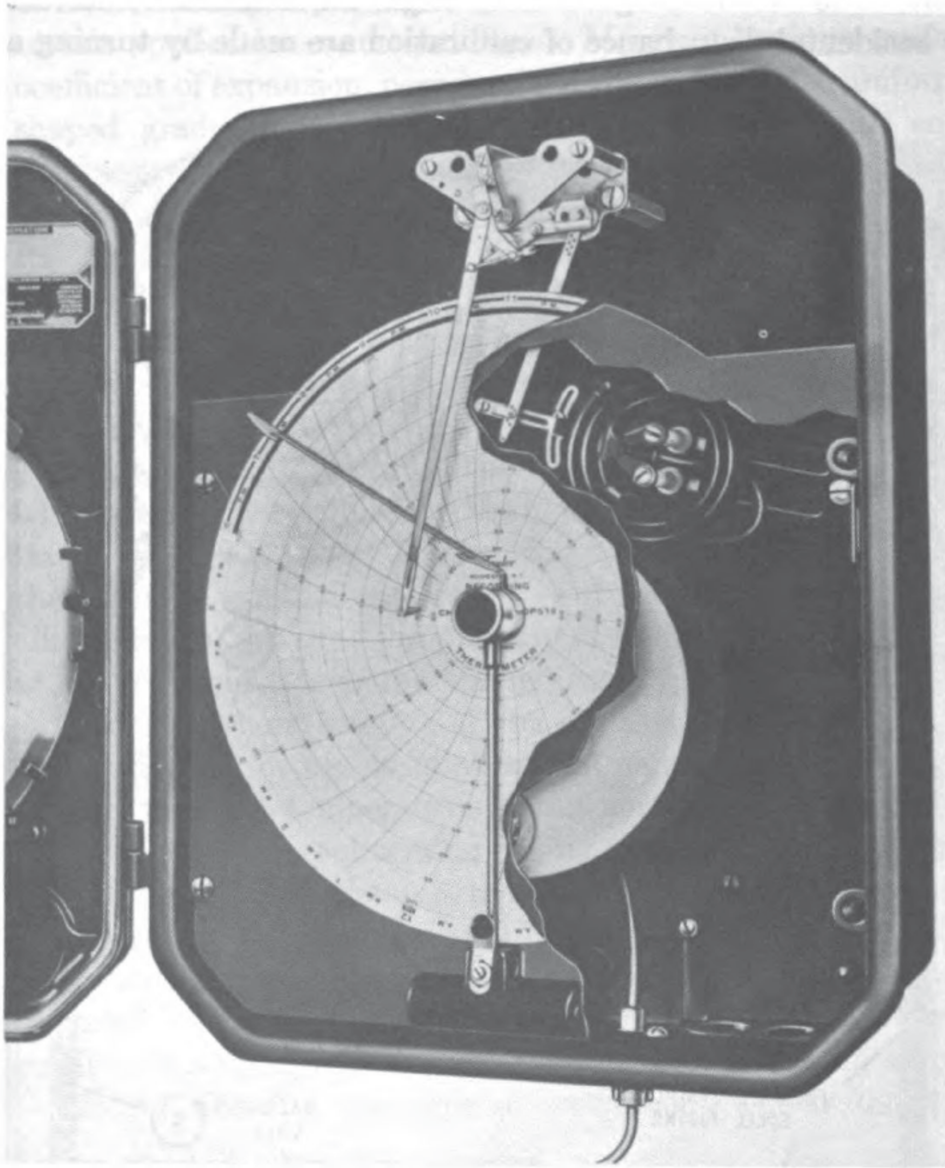


Figure 270. — Cutaway view of single pen recording thermometer.

*Controlling type.* — The Bourdon principle is also used to actuate controlling types such as superheater temperature alarms. As indicated in figure 271, the Bourdon tube in this type of instrument is made in the shape of a helix to which a cantilever arm is mechanically attached. The mercury-filled

bulb is fitted in a well in the superheater outlet line. This alarm-signal-only model is the type usually found in service on naval vessels. As the temperature reaches the upper safe operating temperature of the superheater, say 800° F., the cantilever arm closes the microswitch. When closed, the switch operates electrical devices in the circuit which cause a warning horn or "howler" to sound, and a warning light to come on. The alarm continues to ring until the temperature drops 10° to 15° below the alarm temperature. In some installations, the switch also closes the fuel-oil supply valves to the superheater side of the boiler involved.

Another type of thermal alarm or contact maker employs in place of mercury the principle of the differential expansion of solids. By means of a lever the difference in expansion of these solids (a short ceramic tube and a long steel tube) is multiplied to move electrical switches towards or away from contact terminals. The operating mechanism is all enclosed within a

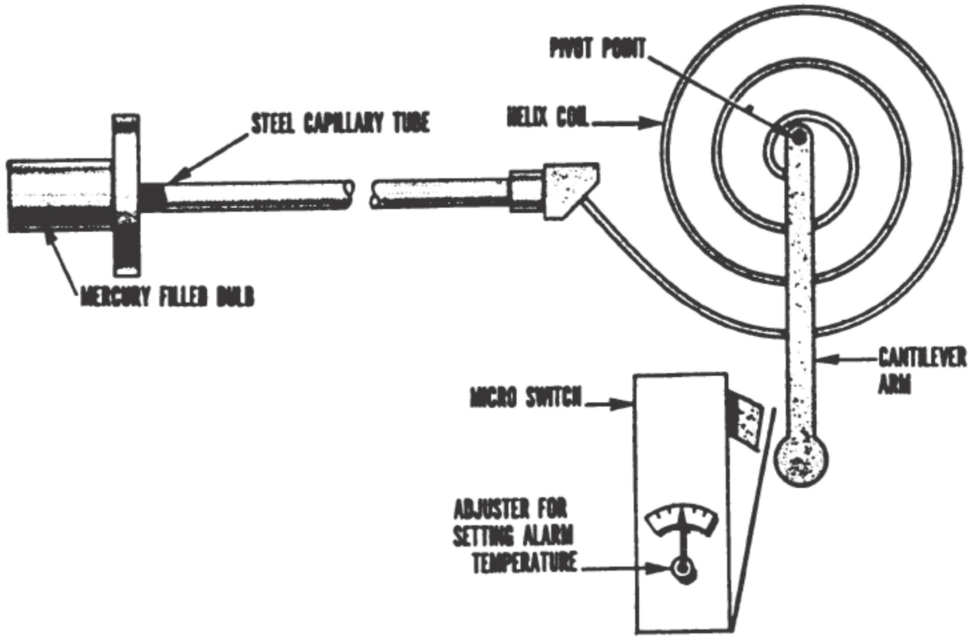



Figure 271. — Diagram showing principle of superheater temperature alarm.

sheet metal cover. These units are safety devices and operate only when the maximum set temperature is exceeded. To change the setting of the alarm, remove the case cover and using

a sturdy screwdriver turn the slotted head of the adjusting screws. The short pin attached to it serves as a pointer over the scale. To adjust for a different temperature, first bring the superheat temperature to the point where you want the alarm to operate. Turn the adjusting screw up to H (high), then turn it down slowly until the alarm just goes off. Do NOT make the adjustment by turning up from below until the alarm goes off. That procedure would give an ON point 20° to 30° higher than the actual existing temperature. (When one of these thermal units goes out of commission, it is replaced with a spare unit, and returned to the factory for repair.)

Superheater temperature alarms are used nowadays as supplemental equipment to superheater low-flow protective

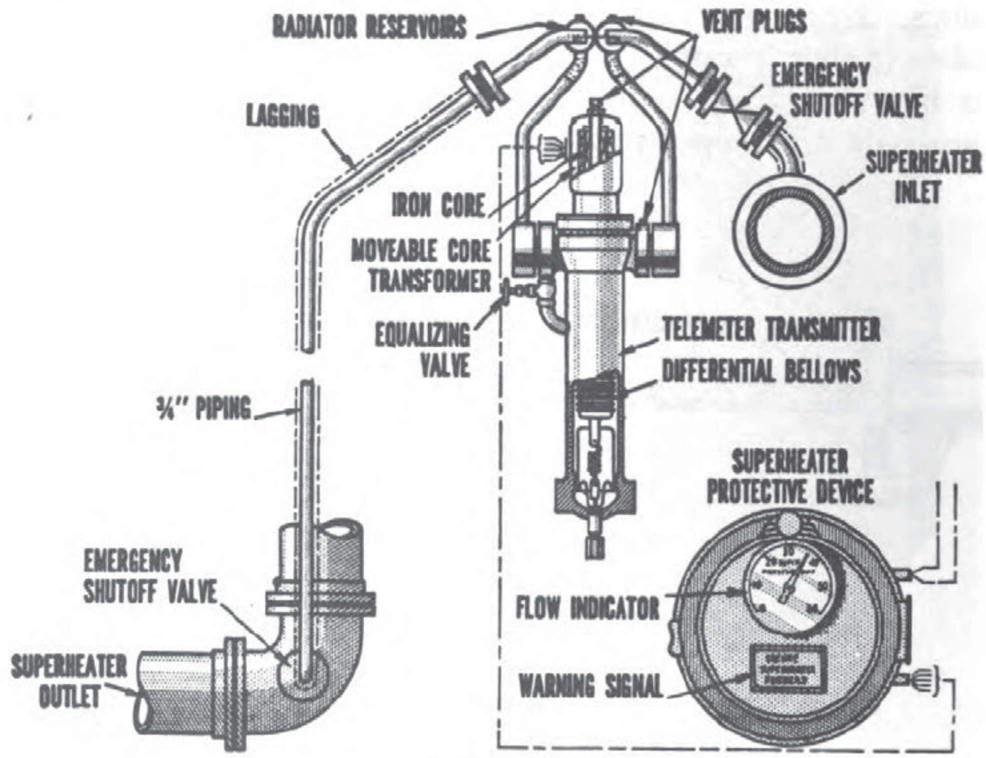



Figure 272. — Superheater low-flow protective device.

devices, which actuate the same set of alarm signals. This low-flow protective device, illustrated in figure 272, warns the men on watch in the engine room of a dangerously low rate of flow of steam through the superheater. It consists of a transmitter

actuated by the difference in steam pressures at the superheater inlet and at the superheater outlet, and an indicator with attached warning howlers. The indicator has a pointer and dial which indicates the amount of the steam pressure difference. The dial is usually calibrated in inches of water (1 p.s.i. = 27.7 inches of water) in order that the small pressure differentials existing at low steaming rates may be apparent. There is also a red light which comes on at the same moment as the rectangu-

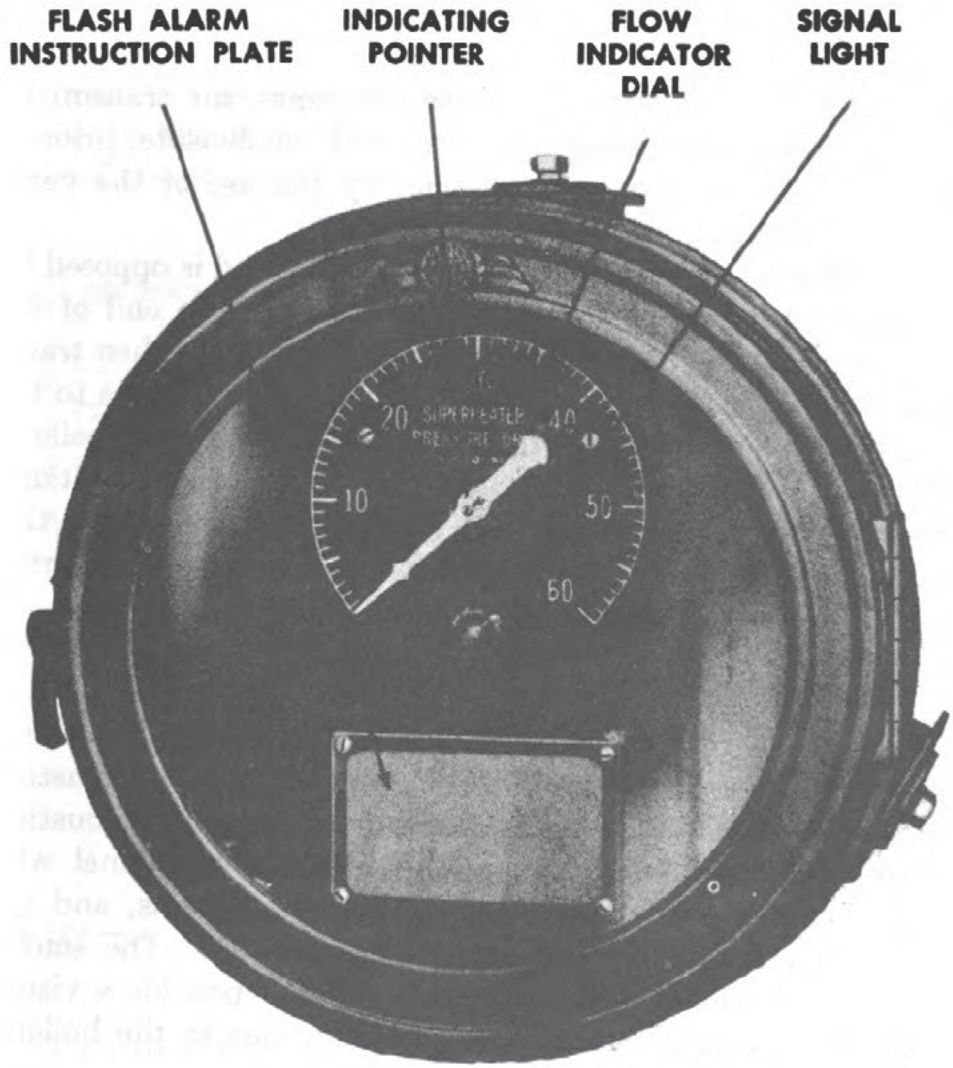



Figure 273. — Protective device indicator.

lar translucent sign below it reading "Secure Superheater Burners." The details of the indicator are shown in figure 273.

The pressure drop is proportional to the steam flow through the superheater. When this pressure drop reaches a dangerously low level, the red indicator light and warning signal comes on, and the howlers sound. The high-pressure connection from the superheater inlet leads to the space in the transmitter outside of the bellows. The superheater outlet pressure is impressed on the inside of the bellows, resulting in a tendency for the bellows to be compressed.

The radiator reservoirs are for maintaining a fixed head of water on the differential bellows. They are installed so that rolling and pitching of the ship will have but little effect on the delicate flow measurement. These reservoirs, the transmitter and the connecting piping, are filled with condensate, prior to placing the equipment in operation, by the use of the vents and the equalizing valve.

The tendency for the bellows to be compressed is opposed by a calibrated balancing spring attached to the free end of the bellows. Any resulting movement of the bellows is then transmitted through the rigid vertical link inside the bellows to the moveable iron core in the transformer located above the bellows cylinder. Motion of the iron core varies the ratio of the voltages across the two output windings in the transformer, and this variable voltage ratio is used to operate the indicator mounted on the boiler control board.

## COMBUSTION CONTROL INSTRUMENTS

Since the security of the fleet at sea requires that ships' boilers operate almost smokelessly, the control of combustion within proper limits is highly desirable. Several combustion instruments have been designed to help the personnel who operate the boilers to (1) meet security regulations, and (2) check the efficiency of the boilers in operation. The smoke indicator and the $CO_2$ indicator and recorder provide a visual means for studying the combustion conditions in the boilers, and flue gas analysis outfits make possible an accurate scientific analysis of the products of combustion.

The smoke indicator is an illuminated lens and mirror periscope-type instrument installed in the uptake of the boiler. By

looking through the eyepiece of this device, the boiler operator can tell, from the amount and color of the smoke, whether furnace combustion conditions are normal. The smoke indicator has no indicating dial or moving parts, and requires only regular cleaning in order to maintain its efficiency in service.

## $CO_2$ Indicator and Recorder

The $CO_2$ indicator and recorder (see figure 274) is the instrument used for determining and recording the amount of carbon dioxide gas ($CO_2$) in the stack gases. The operation of the instrument is based on the facts that the specific weight (the ratio of the weight of a given volume of gas to the weight of an equal volume of air) of stack or flue gas varies in proportion to

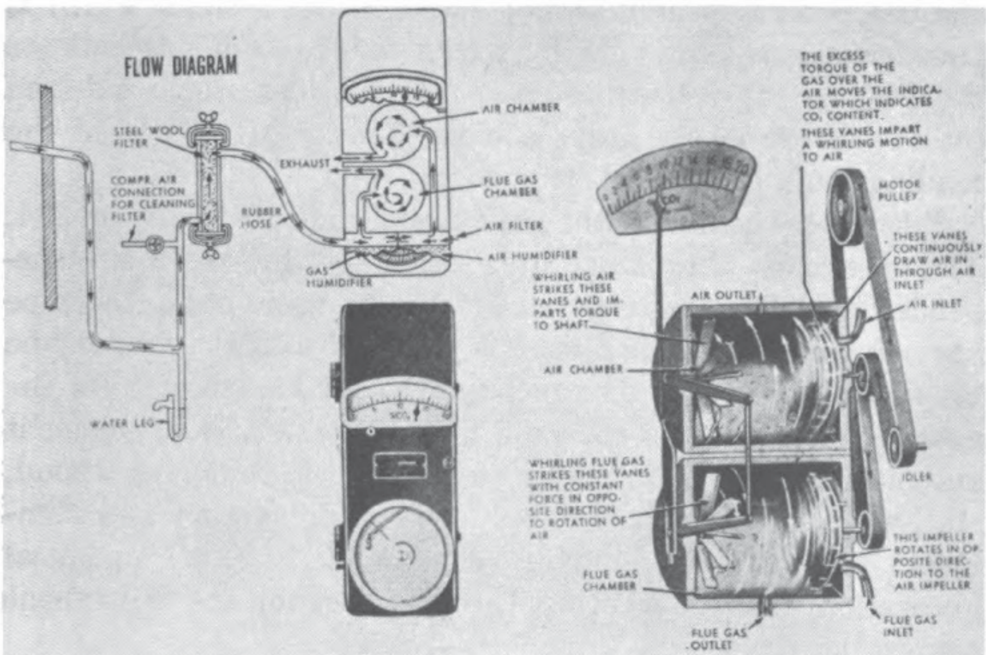



**Figure 274.—A $CO_2$ indicator and recorder, with diagram showing principle of operation.**

its $CO_2$ content, and that $CO_2$ is considerably heavier (about 50 percent) than any of the other components of the stack gas.

The diagram in figure 274 illustrates the principle of the $CO_2$ indicator and recorder in operation. A rotary motion is given to the flue gas by means of a motor-driven fan placed in a

cylindrical chamber. This fan drives the gas against the blades of an impulse wheel located opposite the fan in the same chamber, producing a torque (a force tending to produce rotation) on the wheel shaft. This torque is directly proportional to the density of the flue gas, and therefore to the $CO_2$ content of the gas. To eliminate the influence of changes in fan speed, temperature, humidity and atmospheric pressure, a similar comparing torque is produced by the same motor on another impulse wheel with atmospheric air from a second fan driven in the opposite direction.

*Recorder.* — The two impulse wheel shafts are coupled together by means of two levers and a link. This coupling system is very accurately balanced so as to prevent any rotation of the impulse wheels. However, the difference of the opposing torques permits a limited movement of the system, which is transferred to a pointer moving over a scale calibrated to indicate the $CO_2$ content of the stack gas. The recorder, which is driven by an electric clock, keeps a clear, continuous record of the readings on a circular 24-hour chart.

*Filters.* — The flow of the gases also is indicated in figure 274. The gases pass through a filter inside the uptake, where suspended particles are removed before the gases enter the pipe line. A compressed air service is provided so that soot may be blown off this filter. The moisture which condenses from the gases upon cooling is collected in a water leg, from which it automatically overflows. The gases then pass through a second, steel-wool filter which removes any remaining soot and eliminates the corrosive sulphur compounds through chemical absorption with the steel wool, thus protecting the instrument against corrosion.

*Humidifier.* — From the steel-wool filter the gases flow through the lower part of the humidifier, where they are brought to the same temperature and degree of humidity as the air. The air passes through the other humidifier compartment along with the gases. The humidifier is merely a baffled container of water, with a gastight dividing wall, the gases and air passing over the water surfaces. The air is filtered through a small porous disk attached to the humidifier.

## FLUE GAS ANALYZER

The flue gas analysis *supplements* the information obtained from smoke indicator observations and $CO_2$ recorder charts, giving much more accurate results. The information it supplies is of service to the operating personnel in obtaining better draft regulation and improved firing methods; the flue gas analysis also gives the specific information needed to maintain the boiler's efficiency of operation.

One of the instruments successfully used in the Navy for analyzing flue gas is illustrated in figure 275. It consists of a U-tube manometer draft recorder for measuring pressures, an armored thermometer for determining stack temperatures, the

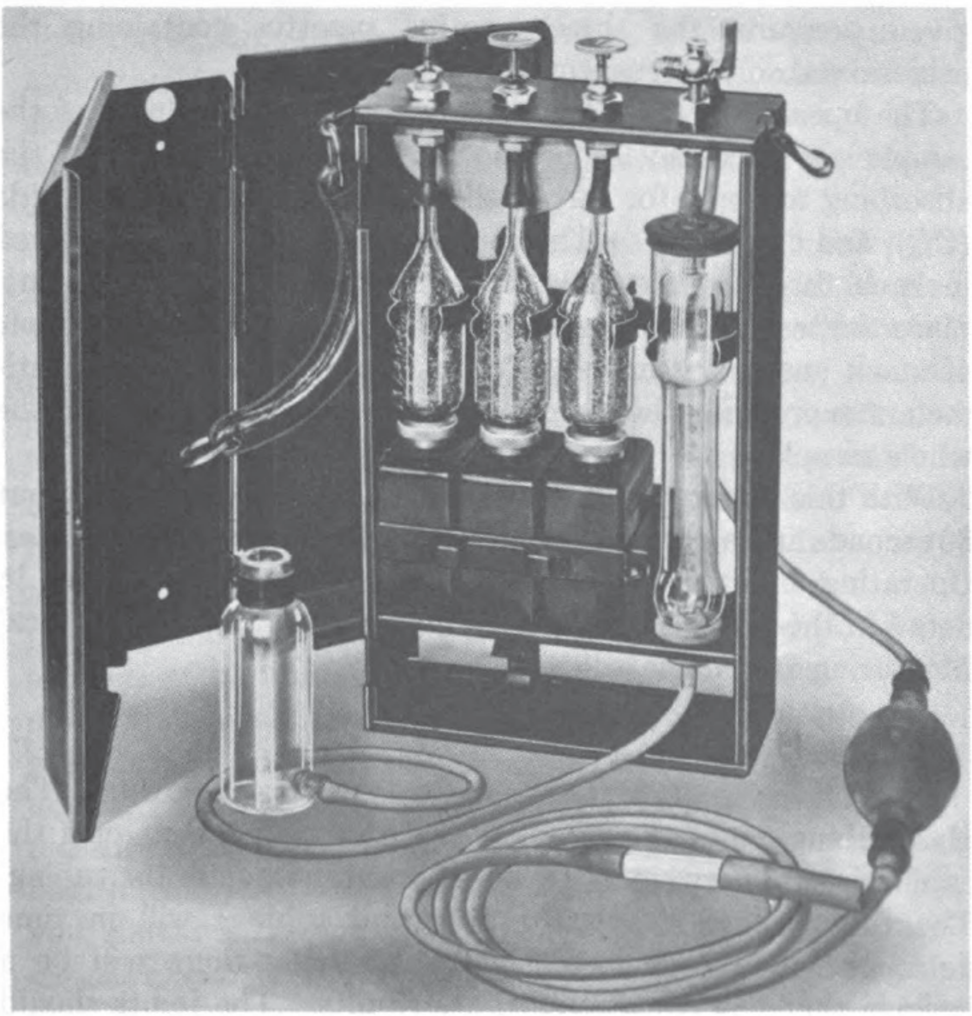


Figure 275. — Flue gas analyzer.

three-unit tester and a compact case for stowage. The analysis with this instrument is made by the use of specific volumes of the stack gases, although in reality it is based upon the determination of partial pressures. According to a well-known law of physics, when a number of gases are confined in a given space each gas occupies the total volume at its own partial pressure; the total pressure is the sum of all the partial pressures. When one of the gases is absorbed by a suitable medium and the remaining gases are compressed to their original total pressure, a volume decrease results, and if the temperature remains constant, this decrease equals the volume absorbed.

This instrument consists of a graduated measuring tube into which the gases are drawn and accurately measured under a given pressure, the three treating pipettes containing the necessary absorbing reagents and an aspirator.

The operation consists of forcing a measured volume of the sample gas successively through the pipettes containing the absorbing reagents for carbon dioxide ($CO_2$), carbon monoxide ($CO$), and oxygen ($O$). The contraction of volume is measured in each case to determine the amount of each constituent. Since the test is usually made on a 100-cubic centimeter sample of stack gas, the amount of each constituent in cubic centimeters represents the percentage of that constituent in the whole sample.

With this apparatus, a $CO_2$ reading can be obtained in about 30 seconds and a complete analysis obtained in about 5 minutes. Operating instructions for this instrument are contained in detail in the *Bureau of Ships Manual*, chapter 87, "Mechanical Measuring Instruments."

### Maintenance

It will occasionally be necessary to clean this apparatus. The glass tubing may easily be cleaned with pipe cleaners, or if the capillaries are very small, by passing water through the tubing. The rubber parts (aspirator bulb and tubing) will in time deteriorate and require renewal; otherwise, there will be a leakage that will prevent accurate results. The joints should be kept tight at all times. The stopcocks are delicate and must

not be subjected to much pressure. Keep them lubricated both for ease of operation and to act as packing.

When the apparatus is not to be used for some time, the pipettes (narrow glass tubes used to transfer flue gas samples) should be emptied and the stopcocks loosened and greased. Water may be left in the water jacket and levelling bottle.

Occasionally wash out the fibrous material in the glass soot filter. The moisture in the flue gases accumulates at this point, and an increasing amount of soot will in time cause excessive JUMPING of the water in the measuring burette when a sample of flue gas is pumped out with the rubber bulb.

## COMBUSTIBLE GAS INDICATOR

In naval shipyards and aboard ship, several types of vapor indicators are used to detect the presence of inflammable or explosive mixtures. This vapor-indicator equipment is often employed on naval vessels during inspection and cleaning of fuel-oil tanks.

An example of the type of vapor indicator that has long been approved for ship's use is the Davis Vapotester illustrated in figure 276. The Davis Vapotester is a compact, self contained portable instrument designed to detect all kinds of flammable gases and vapors in tanks, voids, bulkheads, and similar locations. A hose is attached to the inlet connection and dropped down into the tank interior, and when a rubber bulb is squeezed, a test sample of the tank gas is drawn up into the instrument.

Inside the case of this gas indicator are six dry cells, four sections of platinum resistance wire, and a delicate electrical meter known as a galvanometer. The electrical circuit arrangement is based on the principle of the wheatstone bridge. That device, shown in diagram in figure 277, is ordinarily used to measure electrical resistance. Several of the electrical measuring instruments that you will maintain make use of this circuit, so you should know what it is. A wheatstone bridge has four resistors, two of which, *A* and *B*, are known and fixed. Its terminals are connected to a source of electrical energy, and when the bridge is "balanced" the galvanometer shows no


Figure 276. — Self-contained combustible gas indicator, case removed.

current flowing. The ratio between $A$ and $B$ is then the same as that between the variable resistor $C$ and the unknown resistor $D$. By using the equation $\frac{A}{B} = \frac{C}{D}$ the resistance of $D$ could easily be calculated. For example, if the known values of $A$ and $B$ are 30 ohms and 50 ohms, respectively, and the scale reading of the variable resistor shows 90 ohms when a balance is obtained, then substituting these values in the equation $\frac{A}{B} = \frac{C}{D}$ gives:

$$\frac{30}{50} = \frac{90}{D}$$

$$30\,D = 90 \times 50, \text{ or } 4{,}500 \text{ ohms}$$

$$D = 150 \text{ ohms}$$

You will not have to solve electrical problems like this, but

you can repair these instruments more intelligently if you understand their principles of construction.

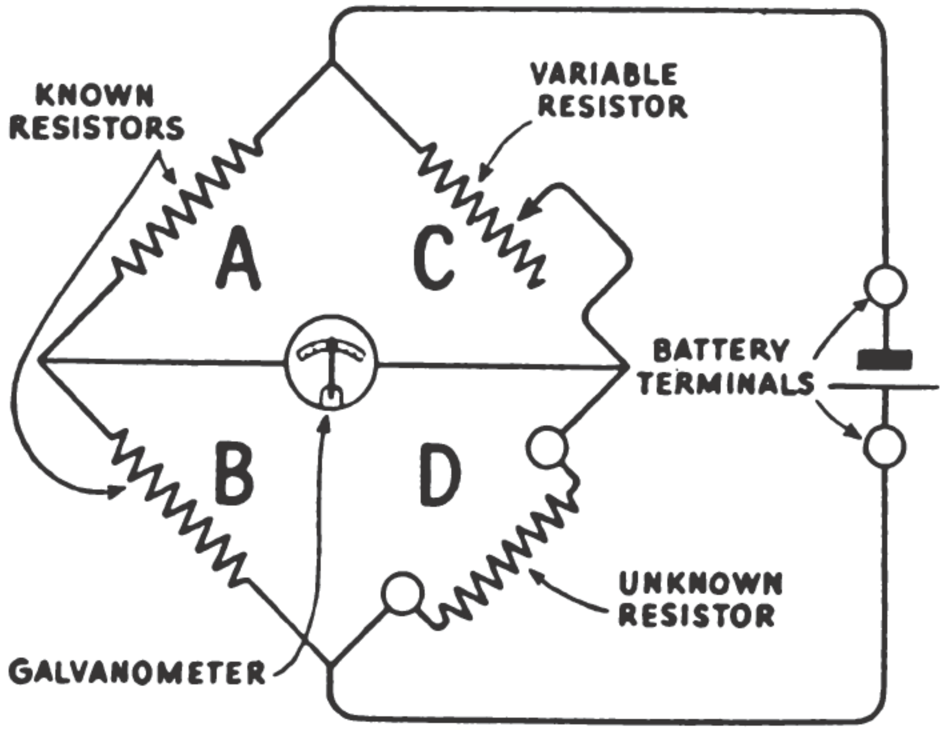



Figure 277.—Circuit diagram of a Wheatstone bridge, used to measure electrical resistance.

The electrical circuit of the Davis Vapotester is shown in figure 278. Two of its four resistors have a fixed value. The third resistance, called the COMPARISON filament, is housed in a completely sealed compartment. The other resistance, the *open* filament, is the active or analyzing filament and is so arranged that air or gas can be drawn over it. When a combustible gas-air mixture is drawn through this open filament chamber, it burns on the surface of the analyzer filament, thereby increasing the latter's temperature. When any metal is heated, it offers a greater resistance to the flow of an electric current through it, and the amount of the resistance varies directly with the amount of the heat. Fundamentally, the operation of the wheatstone bridge is based on this fact and on Ohm's Law, which you read about in *Basic Electricity*, NavPers 10622.

The increased temperature of one leg of the bridge in this

vapor indicator unbalances the circuit, and current flows in one direction through the meter. The amount of current which flows is directly proportional to the percentage of gas present, up to the lower explosive limit. The volt adjustment knob,

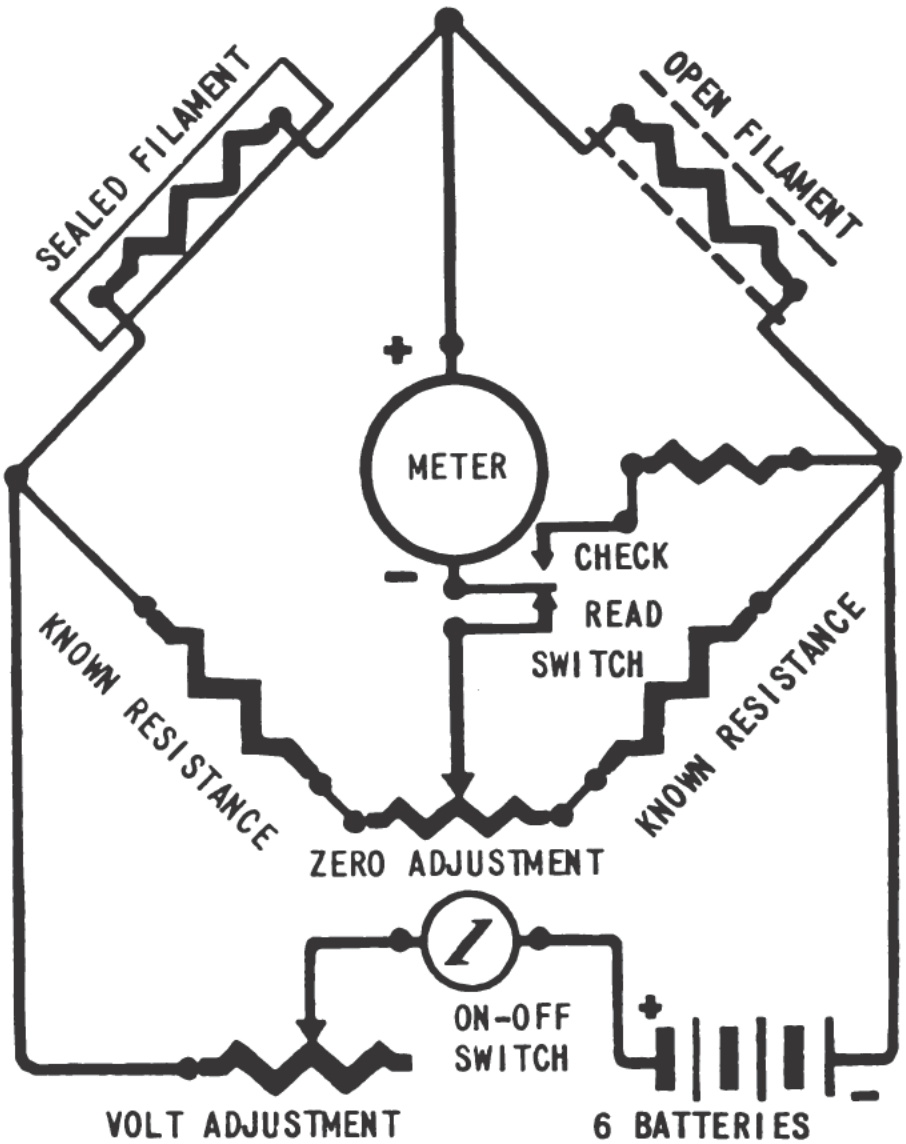



**Figure 278.** — Diagram showing electrical circuit arrangement of the portable vapor indicator. This wheatstone bridge measures the concentration of any combustible gas-air mixture drawn through the instrument.

near the dial, controls the current supplied to the bridge by varying the resistance there, and the zero adjustment is a slide wire resistance which compensates with service for the open

filament deterioration. By means of this adjustment the bridge is balanced to a zero reading on the meter. The dial of the meter is calibrated in terms of the lower explosive limit of hexane, with the result that most of the gases or vapors commonly encountered will read EXPLOSIVE on the meter at a lower concentration than their lower explosive limit.

## Maintenance

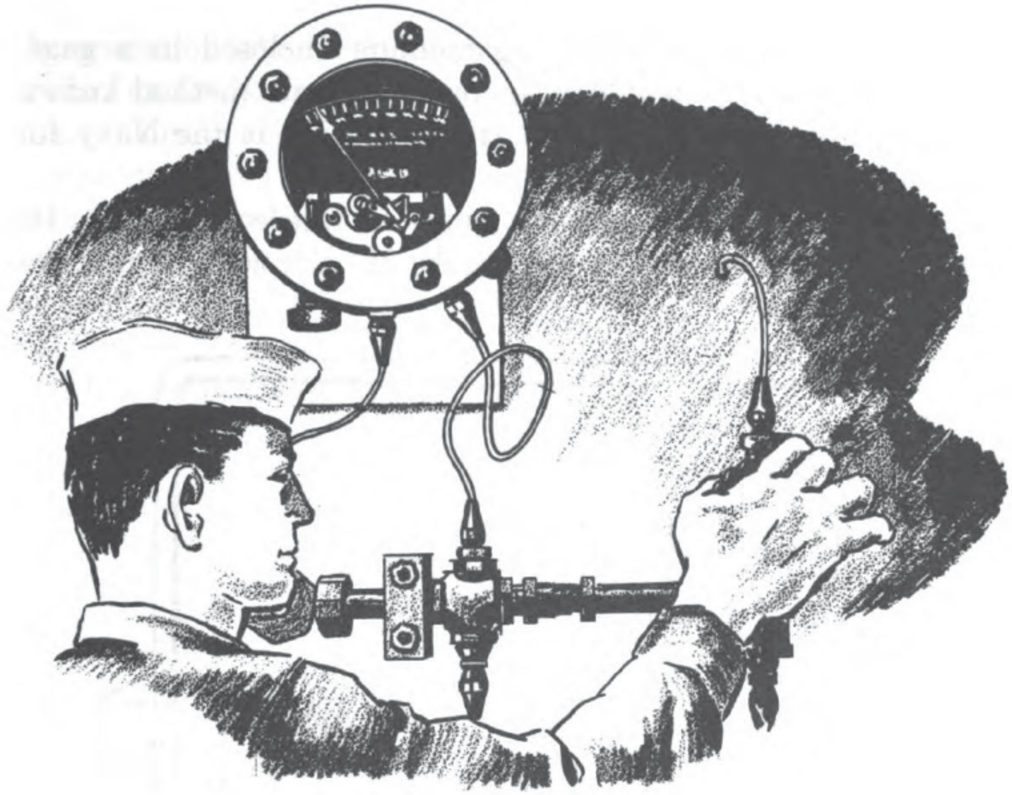
The Davis Vapotester is easy to operate, and the maker's instruction booklet gives full information. The maintenance of this instrument consists mainly of replacing the batteries when the volts reading cannot be adjusted to the green arrow on the dial. (The batteries give 8 to 12 hours of continuous service.) Dead batteries should always be removed as soon as possible from the instrument, since serious harm may result because of dead batteries bursting open. Be sure that the bottoms of all the batteries contact the helical support springs provided for this purpose.

An erratic motion of the needle or a reading far from zero when the battery current is off indicates meter trouble, caused by a foreign particle in the movement. Ordinary adjustment of the meter's pointer is made with a small screwdriver, by turning the screw on the outside of the glass, at the needle pivot.

The synthetic rubber hose should be periodically tested for the presence of any combustible material contamination capable of causing an error in the operation of the instrument. The hose may be cleaned of dust or dirt by flushing it with water. It should be dried, before stowage or further use, by blowing air through it. This portable vapor indicator is equipped with special flame arrestors, designed to give protection against all the common flammable gases and vapors. If for any reason these arrestors become plugged so that a sample of gas cannot be drawn through the instrument, they should be replaced with new arrestors. No attempt should be made to clean or repair the old arrestors.

## QUIZ

1. What are the advantages of mercury from the standpoint of temperature measurement?
2. What are the three main elements of distant-reading indicating-dial thermometers of the Bourdon-type?
3. If the mercury in a thermometer becomes separated, how can it be brought together again?
4. What is a pyrometer?
5. What are the advantages of the pyrometer over the thermometer?
6. How does the indicating resistance thermometer work?
7. What is the operation of a superheater temperature alarm?
8. How does a smoke indicator operate?
9. What is the purpose of the $CO_2$(carbon dioxide) indicator and recorder?
10. Why is the flue gas analyzer used?
11. What is the purpose of the portable vapor indicator?



## CHAPTER 15

# PNEUMERCATORS, FLUID METERS, AND SPEED INDICATORS

## TANK LEVEL INDICATORS

The measurement of the amount of water, oil, and gasoline used on board ship is very important in naval vessels. Computations on estimated needs are checked frequently against the readings of tank gages to assist in engineering, planning, and analysis.

## PNEUMERCATOR GAGES

Tank level indicators (or gages) are used to determine the volume of liquids in a tank or reservoir. The Navy uses two types of these indicators — the hydrostatic-type and the hydraulic-type.

The hydrostatic-type tank level indicator operates on the principle of balancing a head of liquid in a tank against a column

of mercury or other indicating medium enclosed in a gage. This hydrostatic principle is the most accurate method known for determining pressures, and is widely used in the Navy for measuring the contents of tanks.

The Pneumercator gage is typical of this equipment. Its essential elements are shown in figure 279. It consists of three principal parts:

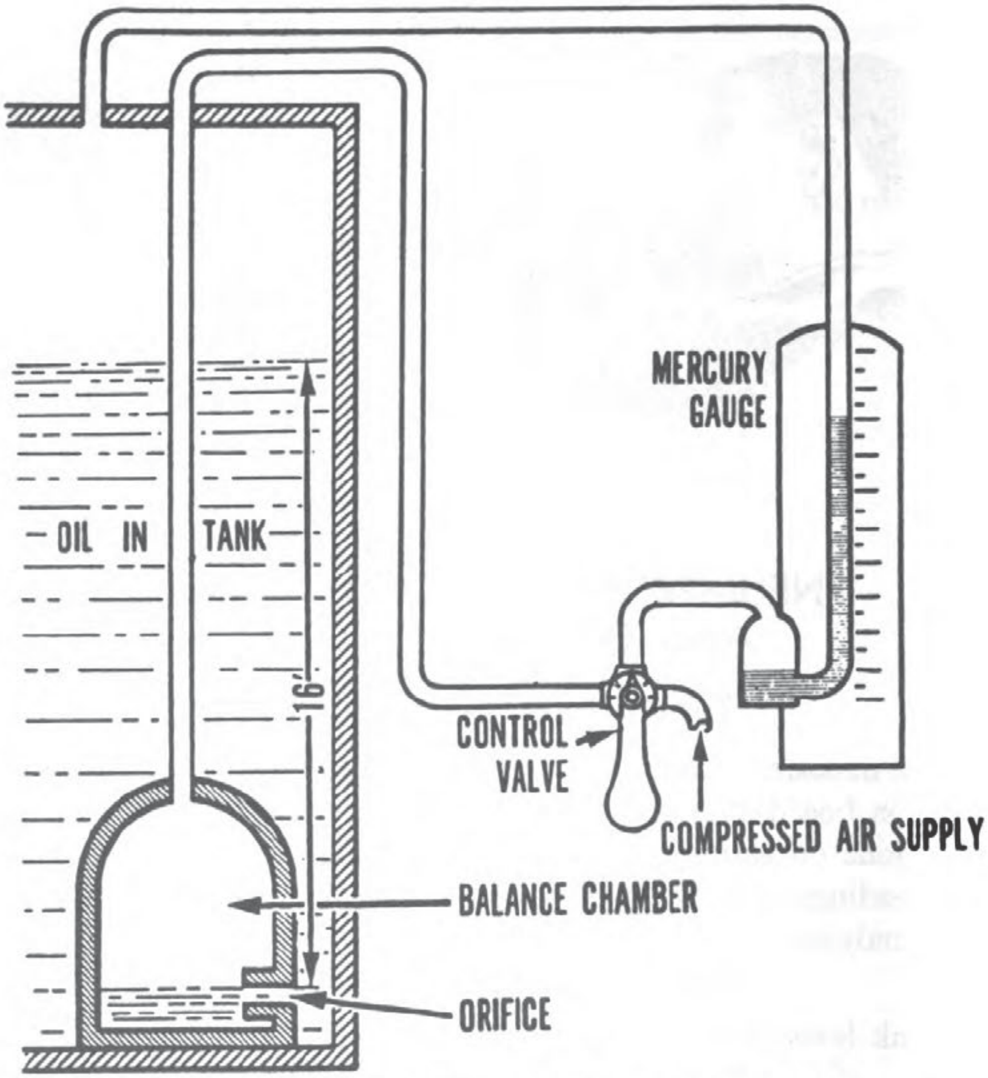



Figure 279. — Principle of the hydrostatic type tank level indicator.

(1). An indicating gage of a size suitable for the tank.
(2). A balance chamber at the bottom of the tank.
(3). Metallic tubing, enclosed in conduits, connecting the gage to the balance chamber.

In operation, the liquid in the tank traps air in the balance chamber and tube line and compresses it against the indicating column, causing the indicating medium to rise in the glass tube in proportion to the depth of liquid in the tank. Since the pressure in the balance chamber bears a direct relation to the height of the fluid in the tank, the gage may be calibrated directly to indicate volume in gallons or barrels in the tank.

An equipment used in many naval vessels is shown in figure 280. This is known commercially as the Tank-o-meter. A

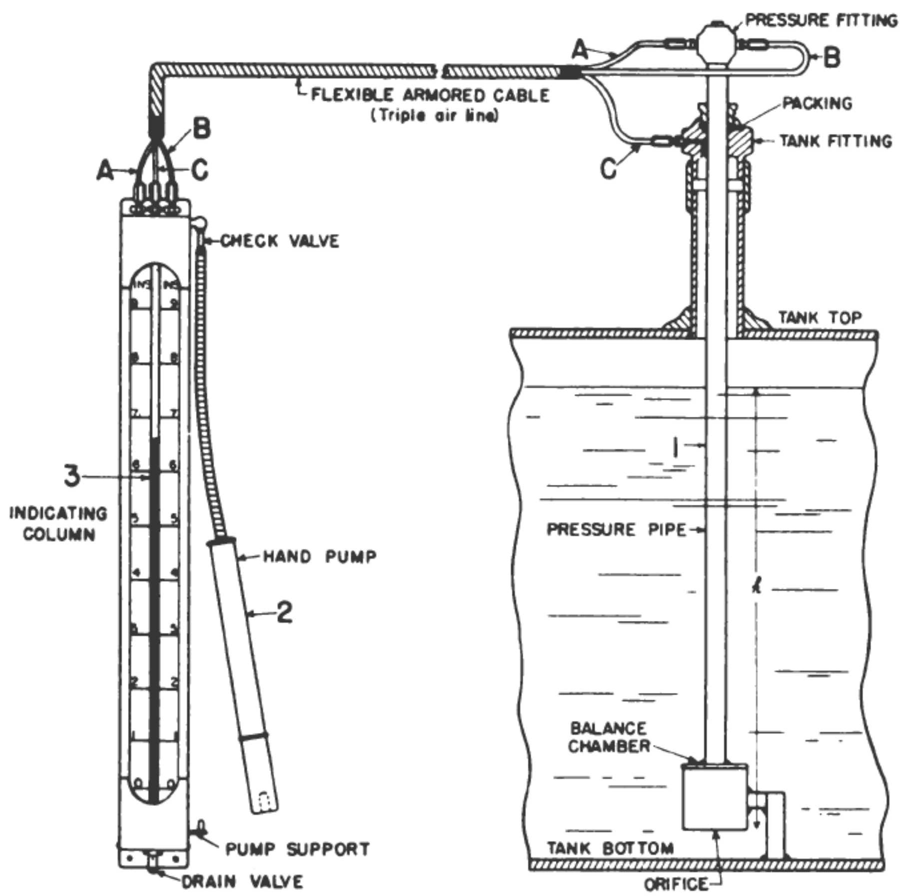



Figure 280. — Typical tank level indicator installation.

pressure pipe (1) is inserted into the liquid and, with a hand air pump (2) air is forced into this pipe through connection (*A*). The pressure through a second connection (*B*) in the pipe is measured by the indicating column (3).

As the pump is operated, the pressure in the pipe will increase

only until it is equal to the head *h* of the liquid. After that point, as more air is pumped into the pipe, air bubbles out through the opening (4). The indicating column, therefore, will continue to rise only until it reaches a point corresponding to the head. Beyond that point, continued pumping will not affect the gage reading.

A third connection (*C*) at the end of an equalizer line connects the space above the liquid in the tank with the top of the indicating column; this tube acts as a pressure equalizing line and guards against an inaccurate reading if at any time the tank is put under pressure or vacuum. Compressed air, when it is available, can be substituted for the hand-operated air pump.

The gage has a scale (5) graduated in units of depth, weight, or volume. Some gages carry two scales, one mounted on each side of the indicating column, allowing a reading in feet and gallons. The indicating medium most generally employed is mercury; but for shallow tanks a red liquid (tetrabromeothane) is used, because it has a greater rise per inch of tank depth and gives a reading easier to read for small amounts. Gages of this type must be recalibrated if the tank's contents are changed to a liquid of another density, as from water to oil or gasoline, because the pressures of different fluids in the tank will differ in proportion to their density.

## Adjusting the Scale

The proper operation of all tank level indicators depends upon the maintenance of a true hydrostatic balance between the head of the liquid and the indicating medium in the gage. A correct reading, therefore, will be obtained only when the scale is properly installed. In adjusting the scale to the gage, the first step is to measure accurately the distance between the lowest point of the tank and the ZERO LINE of the balance chamber, the position of which is marked by a small opening near the bottom of the latter (see figure 279). When this distance has been determined, it is possible to compute the amount of liquid remaining in the tank when the level has reached the zero line of the measuring chamber.

The scale must be adjusted so that when the level of the fluid in the tank drops to the zero line level, it will register the proper amount of liquid in the tank. If this procedure is not carried out, and if the scale is made to read zero when the liquid drops to the zero line level, then all readings will be in error by an amount corresponding to the amount of liquid still in the tank when the liquid level has dropped to the zero line of the measuring chamber. For example, suppose that an oil tank aboard ship has a balance chamber with the zero line three inches above the lowest point of the tank. To correctly adjust the scale for this indicator, the scale should be cut off and placed on the gage so that the lowest gradation will show, not zero, but the amount of oil that is in the tank when the oil level is 3 inches above the bottom of the tank.

## Maintenance

The proper operation of any tank level indicator demands that all the fittings in the connecting lines be perfectly airtight. When trouble arises in these gages, your first consideration should be to assure yourself that the entire system is leakproof.

*Replacing a cracked glass tube.* — Disconnect the copper tube fitting above the gage. Remove the name plate and the instruction plate from the front of the gage (top and bottom), then take off the side rail, the plastic front, and the gage cover. Remove the retaining screw at the base of the gage glass container. Then remove the two screws from the top of the gage, remove the tube gland below them, and lift out the glass tube or remaining parts of it.

*For gages using mercury.* — Wash out the gage base and the tube gland with carbon tetrachloride, and blow them dry with air. Install new tube washers in the gage base and the gland. Replace the tube gland and insert the beveled end of the new glass tube into the washer in the tube gland, pushing the gland up as far as it will go. Make sure that the opaque portion of the glass tube faces the back of the gage. The new glass can then be positioned correctly, with its lower end resting in the gage base. Tighten the two top screws until the glass tube seats firmly in a vertical position. Then re-connect the copper

tube fitting above the gage. (If the mercury needs cleaning, force it through a chamois skin.)

*For gages using red liquid.* — With these gages, follow the same procedure as with those using mercury. However, the old cork washers in these gages must be replaced with new ones, coated evenly with gasket cement just before they are installed. Use glass tubes with flat ends that will seat tightly on the cork washers.

After the new glass tube has been installed, replace the plastic front. Then refill the gage with the proper indicating medium, using a filling funnel (or dropper) furnished by the manufacturer. Pour until the liquid appears in the glass tube at a level with the first line on the scale. When replacing the filling plug, take care that it is PULLED IN airtight; if it allows air to leak into the gage, a false reading will result.

*Testing.* — To test the gage, plug the balance chamber and operate the hand air pump until the mercury or liquid rises to the top line, or gradation, on the scale. Leave the gage on test for about 30 minutes. If the tube line leaks and causes the gage reading to change slowly with change in pressure, go over all the connections carefully with a brush and soapsuds. The forming of minute bubbles will show the location of the leak.

After testing the tube lines and finding them airtight, remove the plug from the balance chamber AT ONCE, to prevent any possibility of the tank filling with liquid while the balance chamber is plugged.

## LEVELOMETERS

Levelometers are gages which operate on the hydrostatic principle, and they employ dial type indicators.

In the Levelometer system (figure 281), an air bell *A* at the bottom of the tank is connected to a flexible bellows *B* in the indicator, or dial, operating on a balance arm *G* by a tubular measuring line *C*. The pump *D* clears the measuring line of liquid by introducing a pressure greater than the pressure caused by the head of the liquid. When the line has been cleared, the excess pressure escapes from the bell and rises to the top of

the liquid. Check valve $E$ prevents air from leaking past the pump when pumping is stopped. The pressure of the air trapped in the measuring line is equivalent to the static head of liquid, which is balanced in the indicator by spring $F$ operating on the opposite side of pivot $H$ on the balance arm $G$.

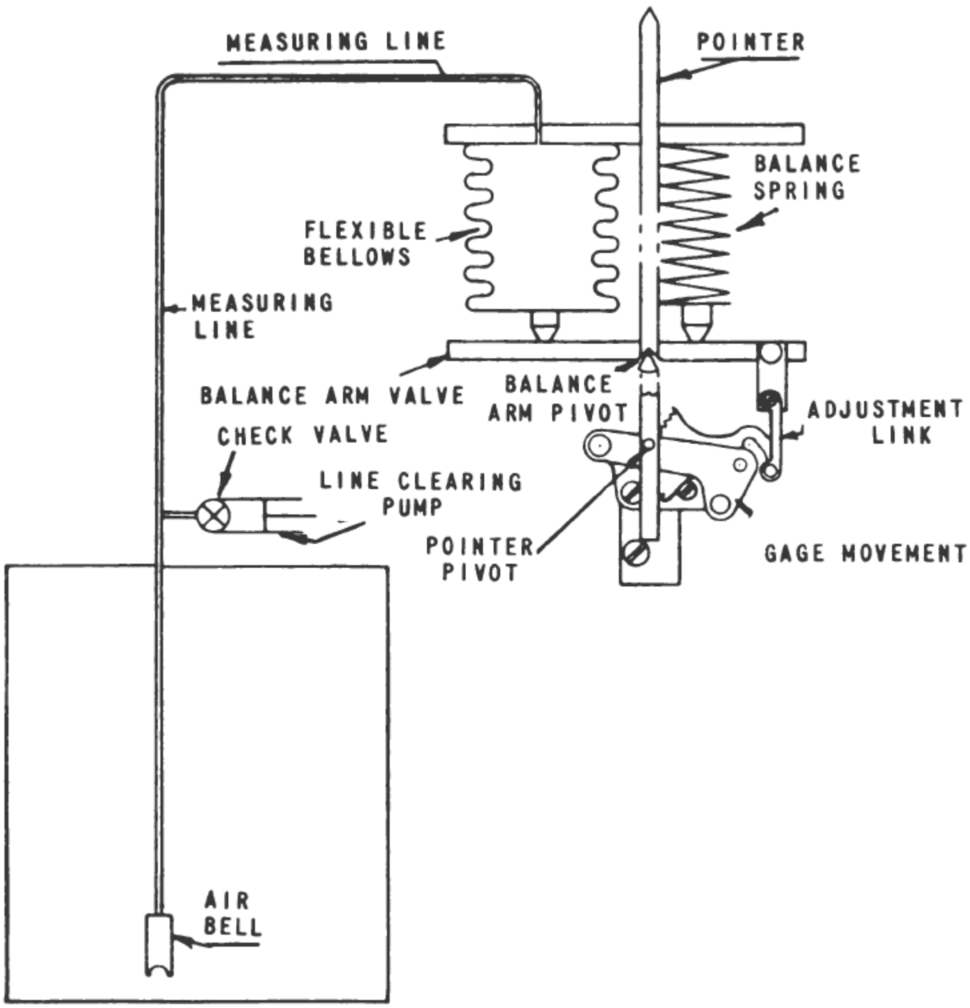



Figure 281. — Levelometer principle of operation.

A change in depth of liquid in the tank will change the pressure of the air trapped in the air bell. These pressure changes are transmitted through the measuring line to the inside of the bellows, causing it to lengthen or shorten in proportion to the pressure. Any change in the length of the bellows is transmitted to the balance arm, causing it to change its position on pivot $H$. The change in the position of the balance arm is further transmitted through link $J$ to the gage movement $K$, causing the

pointer to change its position on the dial in direct proportion to the depth of the liquid in the tank. This system is satisfactory for vented tanks.

The Levelometer is specially constructed when used to measure the contents of tanks under pressure. These models incorporate a compensation feature which operates as follows: The air bell and the equalizer line are connected to an operating manifold (see figure 282) by tubular lines. The measuring line

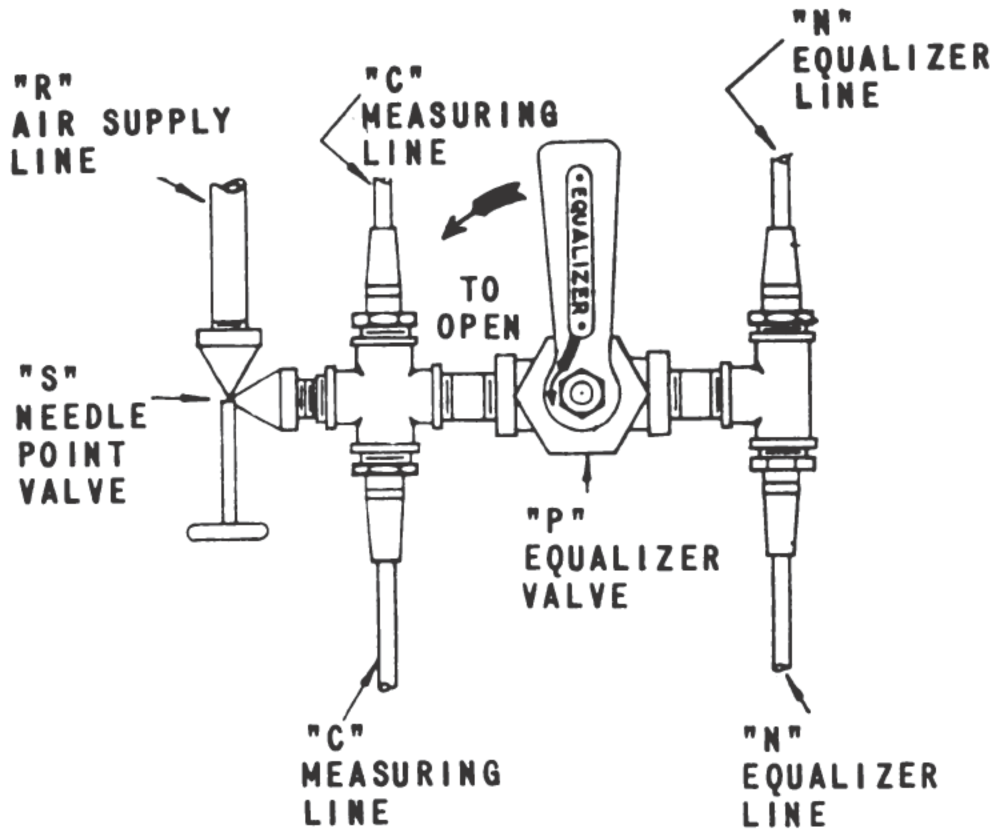



Figure 282. — Operating manifold of Levelometer.

is connected from the manifold to a junction box housed within a pressure-type indicator case, and is connected through a safety valve to the indicator bellows chamber by a tubular line. A sensitive metal bellows which operates on the balance arm is housed in this bellows chamber, and the spring above the balance arm balances any air pressure equivalent to the head of the liquid. An equalizer line is connected to the pressure-type indicator case from the manifold to compensate for tank pressures.

The operating manifold is composed of an equalizer valve *P* which is connected between the measuring line *C* and the equalizer line *N*. An air supply line *R* is connected to the measuring line side of the manifold through a needle point valve *S*. With tanks under pressure, the ship's air supply line is used in place of the hand pump.

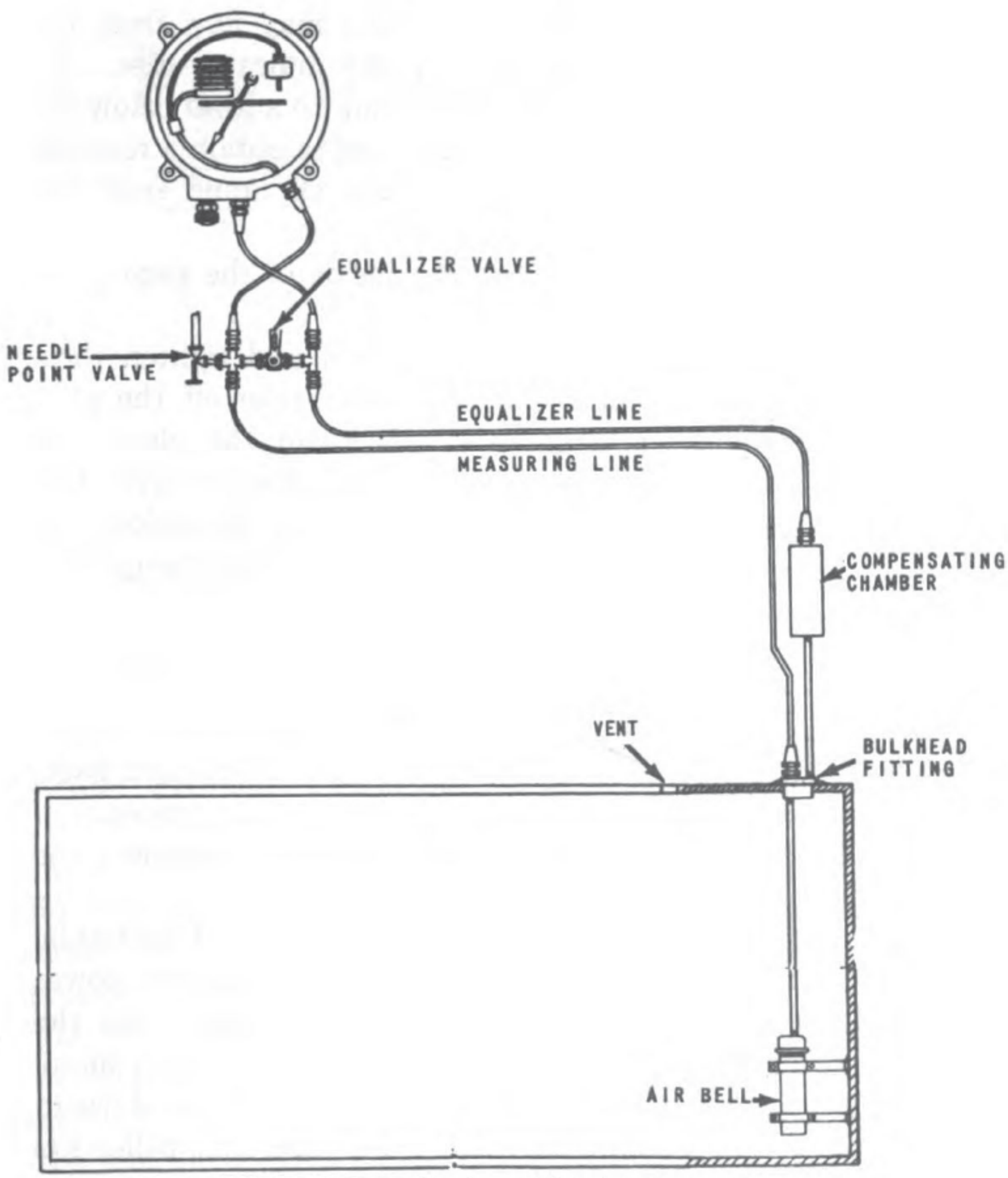



Figure 283. — Single tank Levelometer system.

Levelometers are used to measure the contents of single tanks and multiple tanks. An installation for a single tank is

shown in figure 283. The multiple tank system is operated in a similar manner, the additional tank or tanks being isolated from the other by means of the control valve, when the reading is taken.

### Maintenance

Should a tank be filled beyond capacity, particularly if the equalizer valve has been left open, water may flow from the tank up through the tubing and into the indicator case. To remove water from the case, drain the tank to a level below the equalizer line opening and operate the gage to obtain a reading, thus automatically blowing and draining all liquid from the gage.

Should it be necessary to clean the inside of the gage glass, proceed as follows:

1. Remove the 10 bolts (always loosen and tighten these evenly to prevent cracking the glass) and take off the glass retaining ring, glass and gaskets; (2) clean the glass; (3) reassemble in reverse order, replacing the gaskets with new ones, if necessary; and (4) check to see that all gaskets are carefully alined, in order to guard against cracking the glass.

## LIQUIDOMETER GAGES

Another type of gage, a float-actuated, remote-reading gage, is also used aboard Navy vessels to measure the contents of tanks. This gage, called the Liquidometer, is an example of the hydraulic-type tank level indicator.

The Liquidometer gage operates on the balanced hydraulic system, as illustrated in figure 284, with the operative power derived from a mechanical float and arm movement and the liquid (kerosene) in the transmission system. The two metal bellows in the tank unit are connected with the two bellows in the dial unit. The bracket supporting the tank unit bellows is also provided with a bearing to support the float arm. With any change in the float angle, the bellows in that unit is compressed or elongated in accordance with the float movement.

The dial unit bellows is supported at one end by a bracket

which also provides a bearing connection for the indicator pointer. Those ends of the bellows which face the pointer are connected by bearings through a link which is pivoted on the indicating pointer.

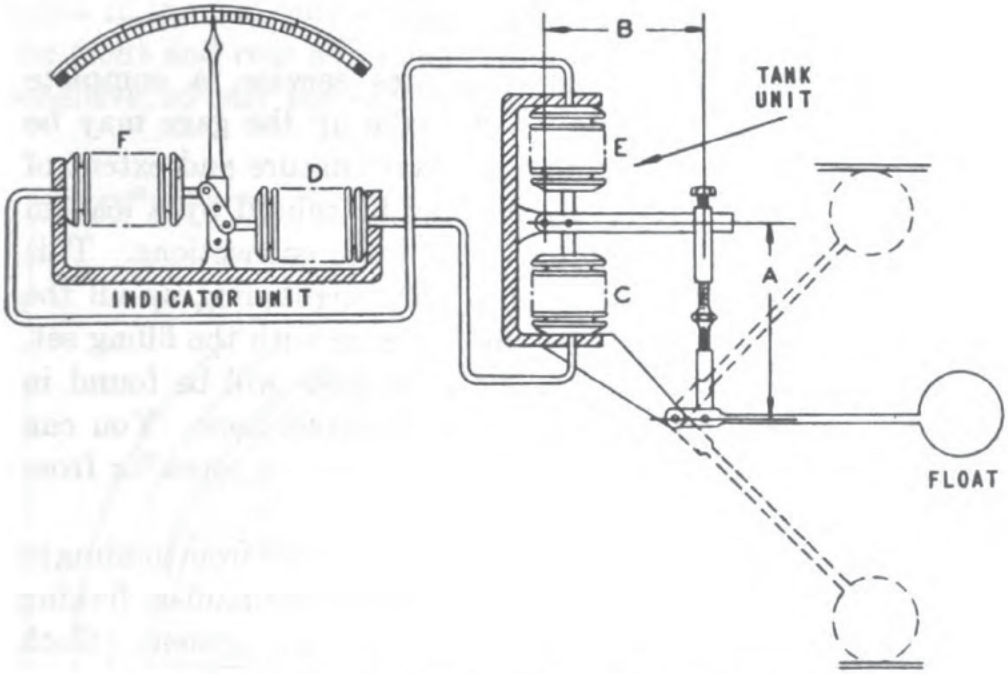



Figure 284. — Drawing showing principle of Liquidometer gage.

The standard Liquidometer gage consists of (1) an indicator assembly, (2) a tank unit, with its float and float arm, and (3) the capillary tubes connecting the indicator with the tank unit and terminating in a line connection box near the tank unit. When the float moves down, the mechanical linkage between the float arm and the tank bellows compresses the bellows *C*, and displaces a portion of the liquid in the transmission system; this liquid travels by way of the transmission tubing into bellows *D* (dial unit), causing the latter to expand. At the same time, bellows *E* (tank unit) because of its connection with the downward-moving float arm, is elongated and takes in more liquid by way of the transmission tubing from bellows *F* in the dial unit. This movement of liquid from *F* to *E* causes *F* to contract and move the pointer. When the float arm moves upward this whole action is reversed. The Liquidometer gage need not be recalibrated when the liquid in the tank is changed. As long as the surface of the liquid moves the float upward or

downward in direct proportion to the depth of the liquid, the gage will read accurately. Liquidometers in large tanks usually have 2, 3, 4 or 5 float units in the tank; these are called multiple-step gages.

## Maintenance

When a Liquidometer gage requires service, a complete examination of all the units which make up the gage may be necessary in order to determine the exact nature and extent of the trouble. Defective operation may be caused by a leak in the bellows or capillary tubing, or by loose connections. This condition should be checked by (1) first tightening up all the connection fittings, and (2) testing the gage with the filling set. Complete instructions for making these tests will be found in the *Service manuals* supplied by the manufacturers. You can obtain these instructions from the engineers' log room, or from the repair officer.

Unsatisfactory operation of the gage may result from binding in the various bearings and bearing pins of the mechanism linking the movement of the float to the transmission system. Such trouble can be eliminated by checking the adjustments and providing full freedom of operation at the various linkage connections in the transmission system.

After all linkages have been freed, the indicator pointer should move from Empty to Full position on the dial as the float is moved from the bottom to the top of the tank. If the gage still fails to operate satisfactorily, it may be that a leak has developed somewhere in the transmission system (bellows and capillary tubes). Such a leak is located by the *Service manual* procedures mentioned above.

## Pointer Adjustment

Two adjustments are made so that the pointer will indicate accurately. The first is the positioning of the adjustment block on the adjustment lever; this controls the amount of pointer travel relative to the float travel. The second is the positioning of the pointer adjustment screw which controls the pointer position. (See figure 285.)

When making these adjustments, first slowly raise the float to its uppermost position in the tank. The pointer should then indicate the red dot (empty) on the dial. If it fails to do so, lower the float to its bottom position, loosen the block lock screw in the dial unit and shift the adjustment block by moving the front and rear adjustment nuts. (This adjustment is very sensitive, so only the slightest move should be made at a time.)

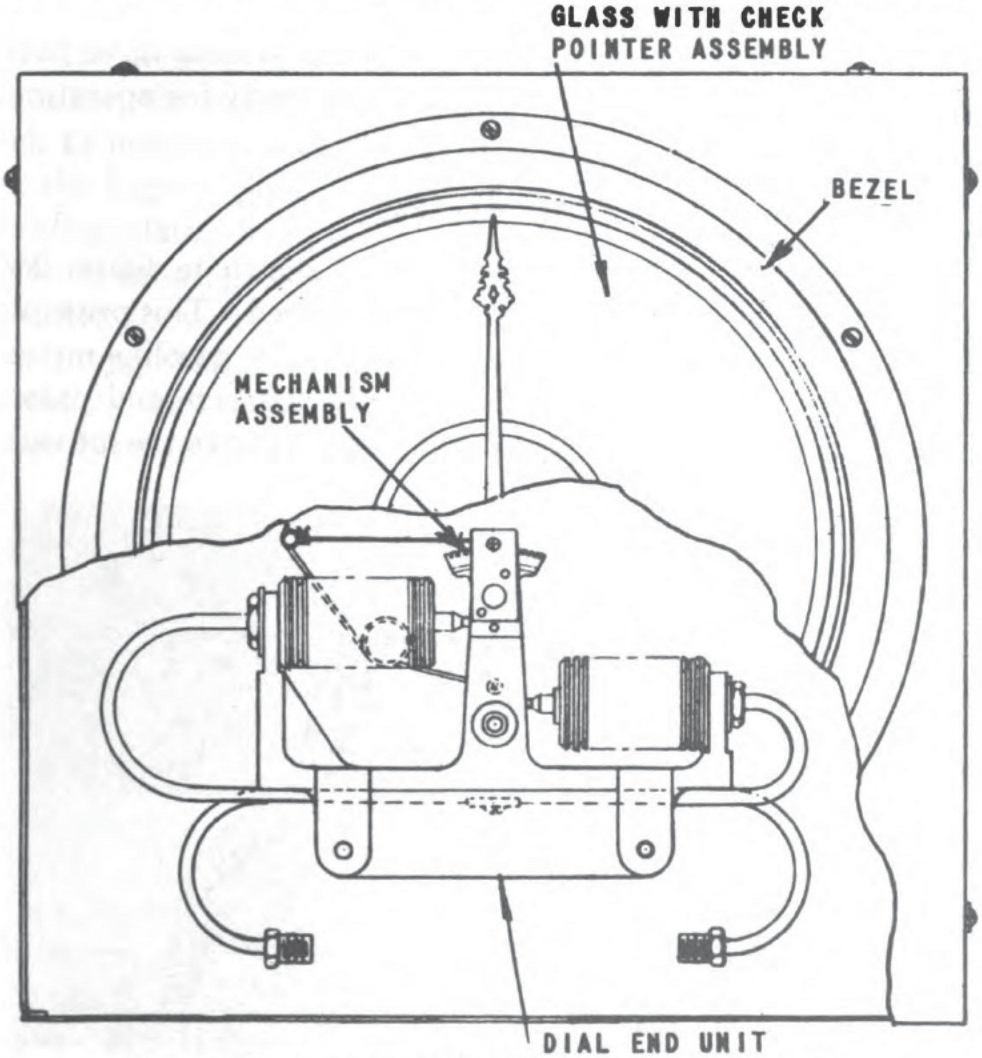



Figure 285. — Diagram of Liquidometer indicating mechanism.

The adjustment block is moved *towards* the housing to increase, and *away* from the housing to decrease, the travel. When this adjustment has been completed, lock the adjustment block tightly in its new position, and tie the float up to its top position.

Next, with the float in its uppermost position, turn the pointer

adjustment screw (directly below pointer) to bring the pointer to the red dot. If the pointer still fails to indicate correctly, repeat both of these operations. It may be necessary to repeat them several times before correct results are obtained. With a gage of this type no new dial calibration is necessary when the tank's contents are changed. So long as the float is raised or lowered by the surface of the liquid, the correct volume of the tank's contents will be indicated on the dial.

When all the adjustments for the entire system have been completed and properly locked, the gage is ready for operation.

## FLUID METERS

The disk-type commercial fluid meter shown in figure 286 operates by displacement of the liquid measured. This principle of operation applies equally to an oil, water, or gasoline meter. Oil, let us say, enters the meter from the left side and passes upward through a strainer into the gear space above the measur-

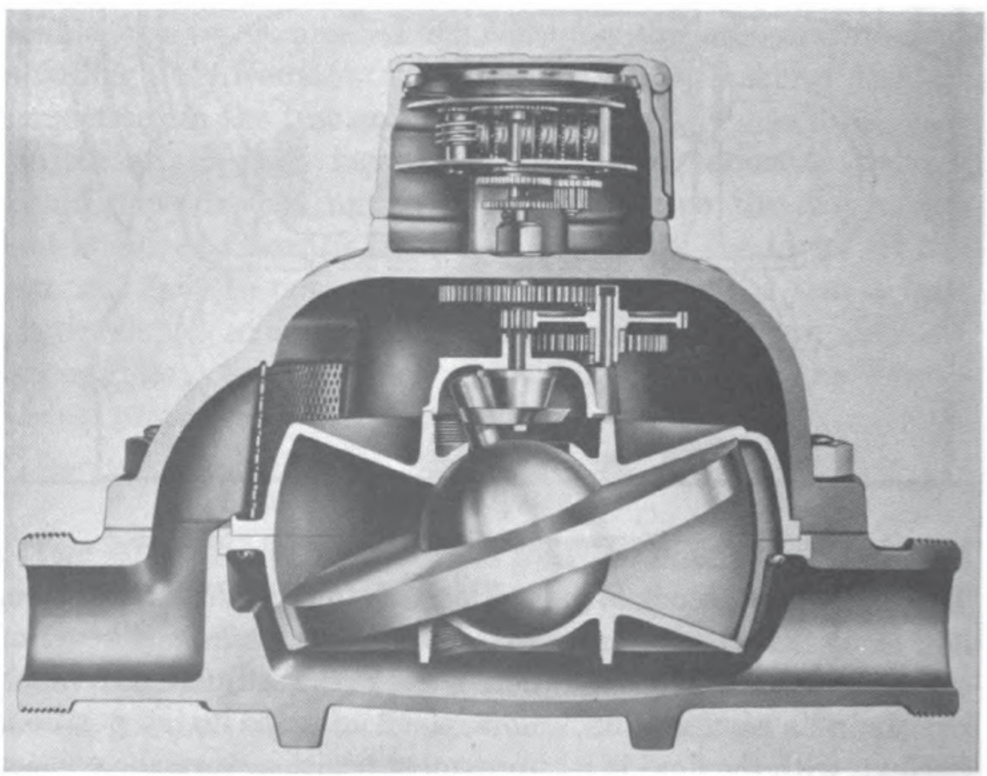


Figure 286. — Disc-type fluid meter.

ing chamber. From there it flows down into the measuring chamber, through an entrance port in the side of that chamber.

The oil then enters the disk chamber on the left-hand side of a fixed vertical dividing plate. The disk in the measuring chamber is free to nutate, or rock around, on its lower bearing surface, but is not free to rotate because of the fixed plate. This nutational movement is similar to that of a spun coin just before it settles on a flat surface.

If the meter starts with the disk tilted up on the side of the chamber, the weight of the oil as it flows around will force the disk to nutate in a clockwise direction, as viewed from above. As the highest point of the disk passes directly opposite the dividing plate, that position of the disk will prevent any more oil from entering at its bottom. But meanwhile, oil has started to enter above the disk. That oil will sweep the fluid below out through the measuring chamber's exhaust port at the right. While the disk continues to nutate, the pin extending from the upper bearing sphere rotates the gear counter arm (figure 287).

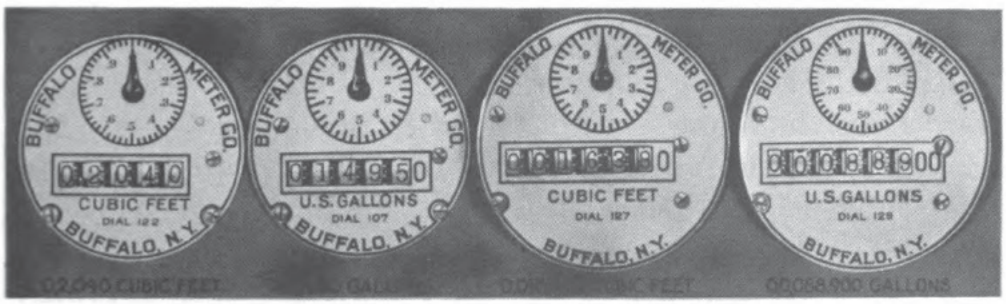



Figure 287. — Fluid meter dial readings.

As the pin moves around, it is guided by the cone-shaped bearing housing which supports the counter arm shaft. Although the disk can never attain a truly horizontal position, the flow of the liquid through the meter is even and continuous.

## Reading Fluid Meters

Reading of the meter register is important, since accurate measurements mean nothing if the quantity of liquid used is not read correctly. To read a straight-reading register, take the reading of the fluid rollers in the usual way and place the reading of the dial hand to the right of those readings. For example, in

figure 287, the rollers on the second dial from left read 01495 and the hand reads 0, making the correct reading 14,950 gallons. If the hand circle indicates a maximum reading of 100 gallons (as on dial at right) instead of 10, the reading of the hand becomes the last two figures in the final reading. For example, if the rollers on that dial read 889 and the reading of the hand was 90 instead of zero, the final reading there would be 88990.

## Maintenance

Fluid meters are subject to certain operating difficulties which you must be able to recognize and correct. Instructions for testing, cleaning, and repairing these meters are furnished by the manufacturers. By following their recommendations, you will soon learn how to locate the trouble and make necessary repairs.

Fluid meter difficulties generally fall into one of the following cases:

1. *Meter stops registering.* — To correct this, first make sure that liquid is actually flowing through the line. If so, see whether the trouble is in the register or in the submerged works. Remove the register box and see if the driveshaft passing upward from the meter body turns when liquid is flowing. If it does turn, then the trouble is in the register. If it does not turn, the trouble is inside the meter body, which must then be opened.

2. *Meter runs inaccurately by constant percentage.* — If the error is no more than 5 percent and the meter is not too old, this may indicate an error of original calculation, or an error resulting from slight wear or change of viscosity of the liquid measured.

3. *Meter overregisters erratically.* — This indicates that air, steam, or other gases are being passed through the meter along with the liquid. The remedy is to keep the air or gas out at its source or, in certain cases, to install an air release valve ahead of the meter. Changing the meter calibration cannot correct this kind of trouble.

4. *Meter under-registers erratically.* — This trouble may be caused either by severe wear, or by partial clogging due to foreign matter. In such cases it is advisable to open the meter

to see whether cleaning will correct the trouble.

5. *Meter operates, but dial hand jumps ahead.* — This indicates difficulty in the meshing of the gearing, usually in the change gears. The gears may be worn to the point where the tops of the teeth strike on each other, or the gears may mesh too tightly. In such cases, follow the manufacturer's instructions for adjusting gears, or for replacing worn gears.

## TACHOMETERS

### Mounted Type

Tachometers indicate the speed of rotation of a machine in terms of revolutions per minute. The mounted types are made for continuous operation, and are mounted on the gageboard or bulkhead. There are several portable types available.

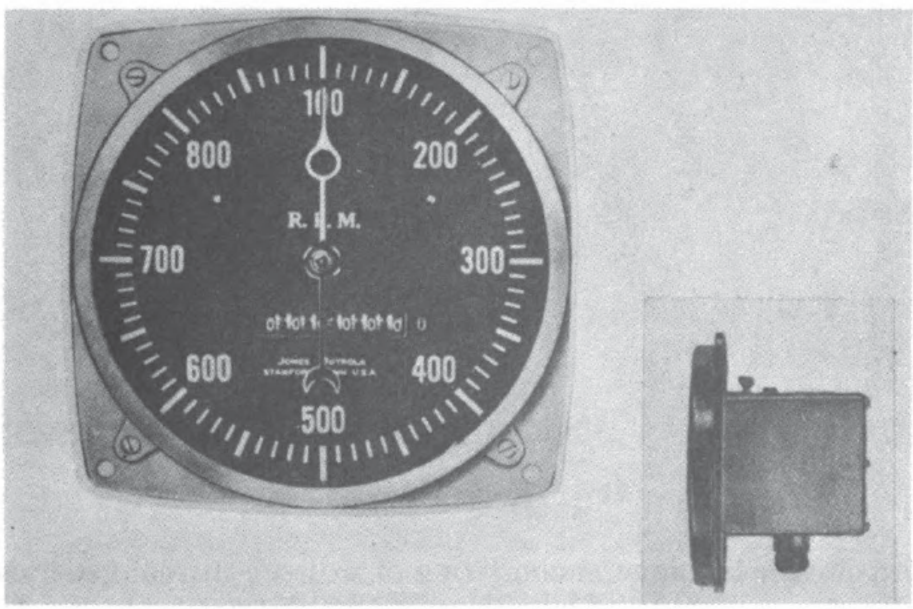



Figure 288. — Tachometer, mounted type.

When the continuous operation model is used, the tachometer head is mounted near the shaft of the engine whose speed is to be measured; the first six inches of the flexible shaft is also fastened firmly in place, to protect the instrument from excessive wear or breakage of the inner cable, and to prevent unstable pointer operation.

A tachometer of the type in use on many Navy ships is illustrated in figure 288. Its appearance is similar to that of the simple dial gage, with the pointer indicating the r.p.m. speed directly. It depends for its action upon the centrifugal force of three revolving weights in a mechanism commonly known as a governor. Each weight is connected with a fixed spider on the governor shaft by a hinged pin that allows it to swing outward as the speed is increased. The movable spider slides over the shaft and operates a spring which balances the centrifugal force at a given speed, and acts as a restoring force when the speed is reduced. The essential parts of this instrument can be seen figure 289.

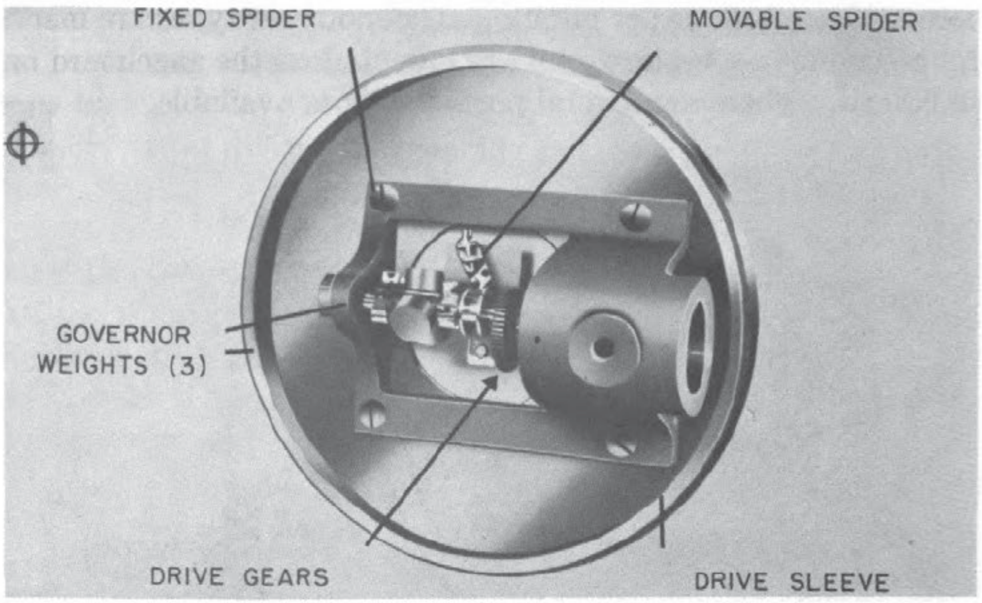


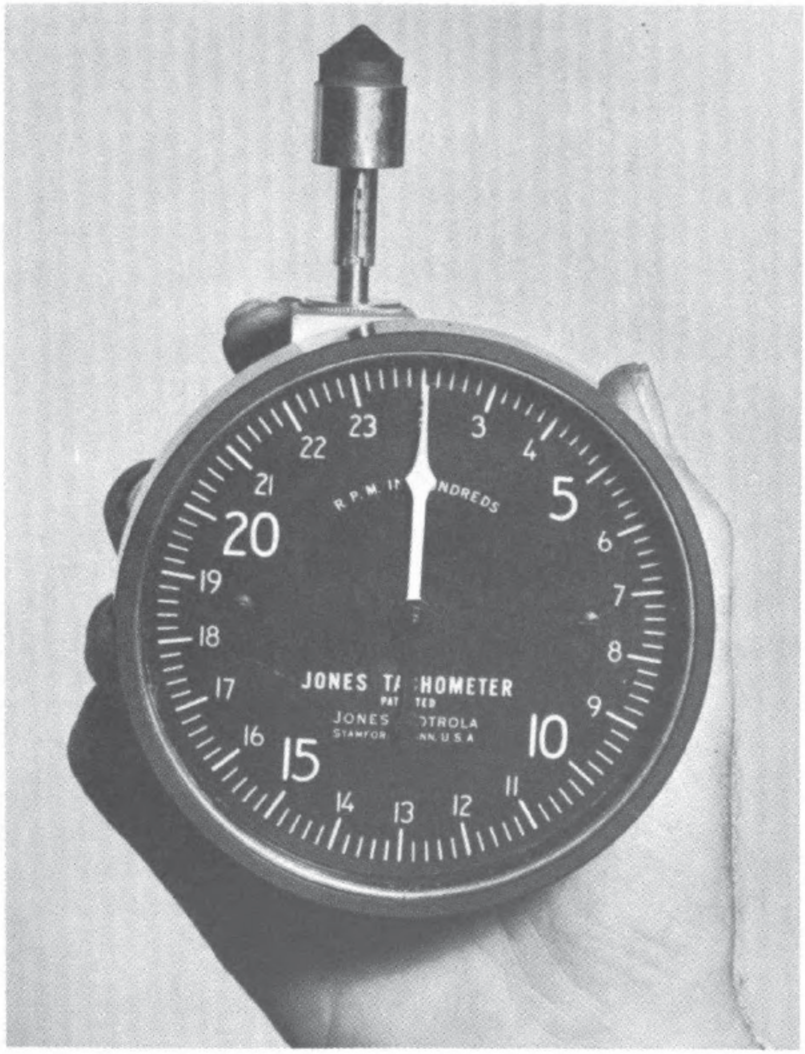

**Figure 289. — Interior view of tachometer.**

An electric tachometer consisting of a direct-current generator with a distant-mounted indicating voltmeter dial is also used in the Navy.

## Portable Type

Two types of portable tachometers are used in the Navy: The conventional centrifugal or fly-ball governor which reads in r.p.m. directly (figure 290) and operates on the same principle as that described above; and the chronometric hand tachometer, a repeating type of combination watch and revolution counter,

which does not show instantaneous speeds but whose hands stop automatically at positions which indicate the measured speed.




**290. — Tachometer, ordinary portable type.**

When the chronometric tachometer is placed against the shaft under test, the spindle will rotate but the hands will remain stationary. When the starting button on the side is pressed, the hands will begin to rotate and will finally stop at a point indicating the average speed in r.p.m. for the operating time. After the reading has been taken, the button is pressed again, and the hands return to zero. The watch is then wound for

the next test. A tachometer of this type is illustrated in figure 291.

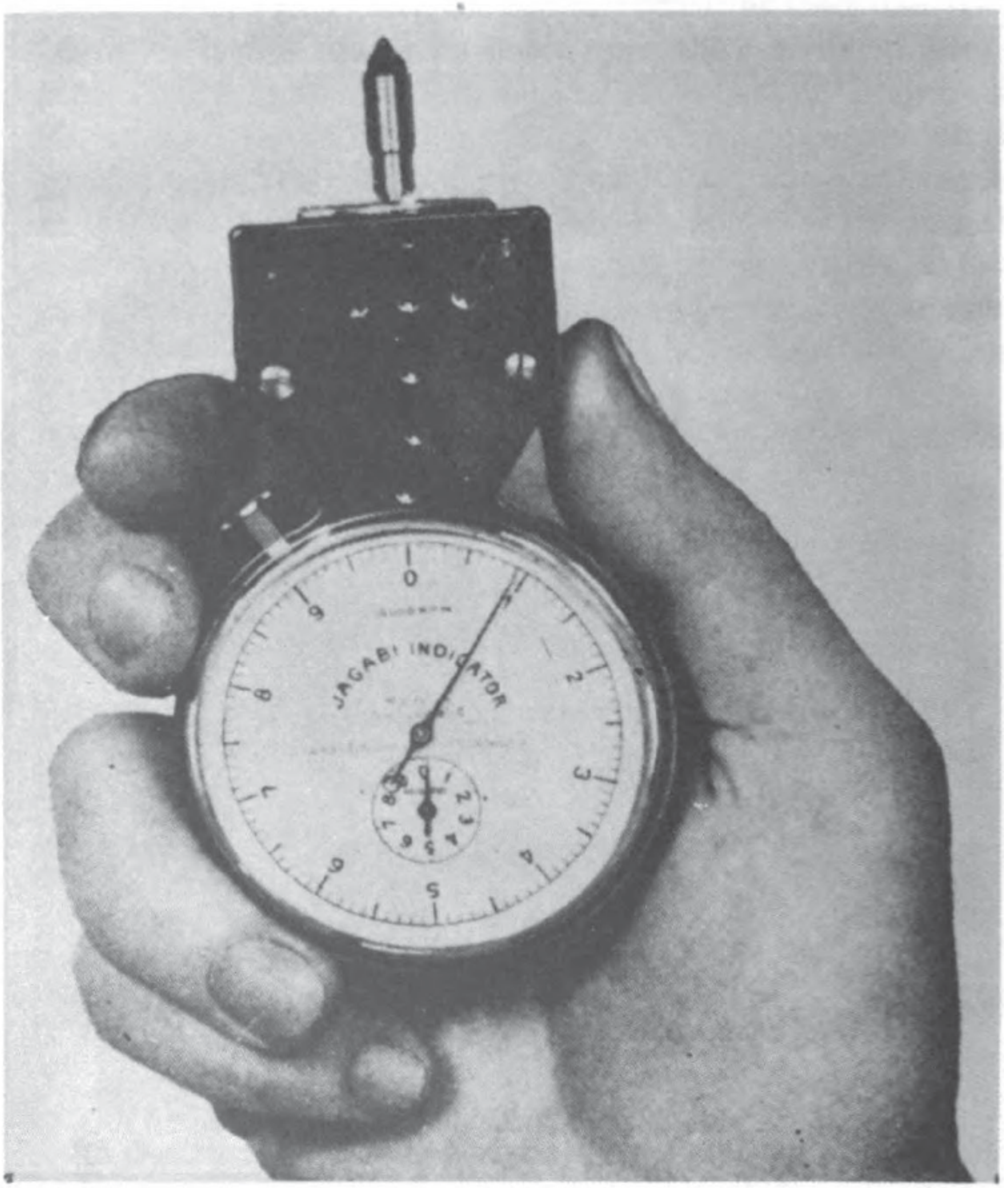



Figure 291. — Tachometer, chronometric type.

Where rotating shafts are not readily available (as may be the case with steam turbines) the vibrating-reed resonance tachometer may be used. This type (figure 292) operates simply by contact with the machine under test. The speed is indicated by the visible vibration of accurately tuned steel reeds. These reeds are each tuned to a different frequency,

and mounted with their free ends visible. The vibrating element is essentially a multiple-pronged tuning fork. When this reso-

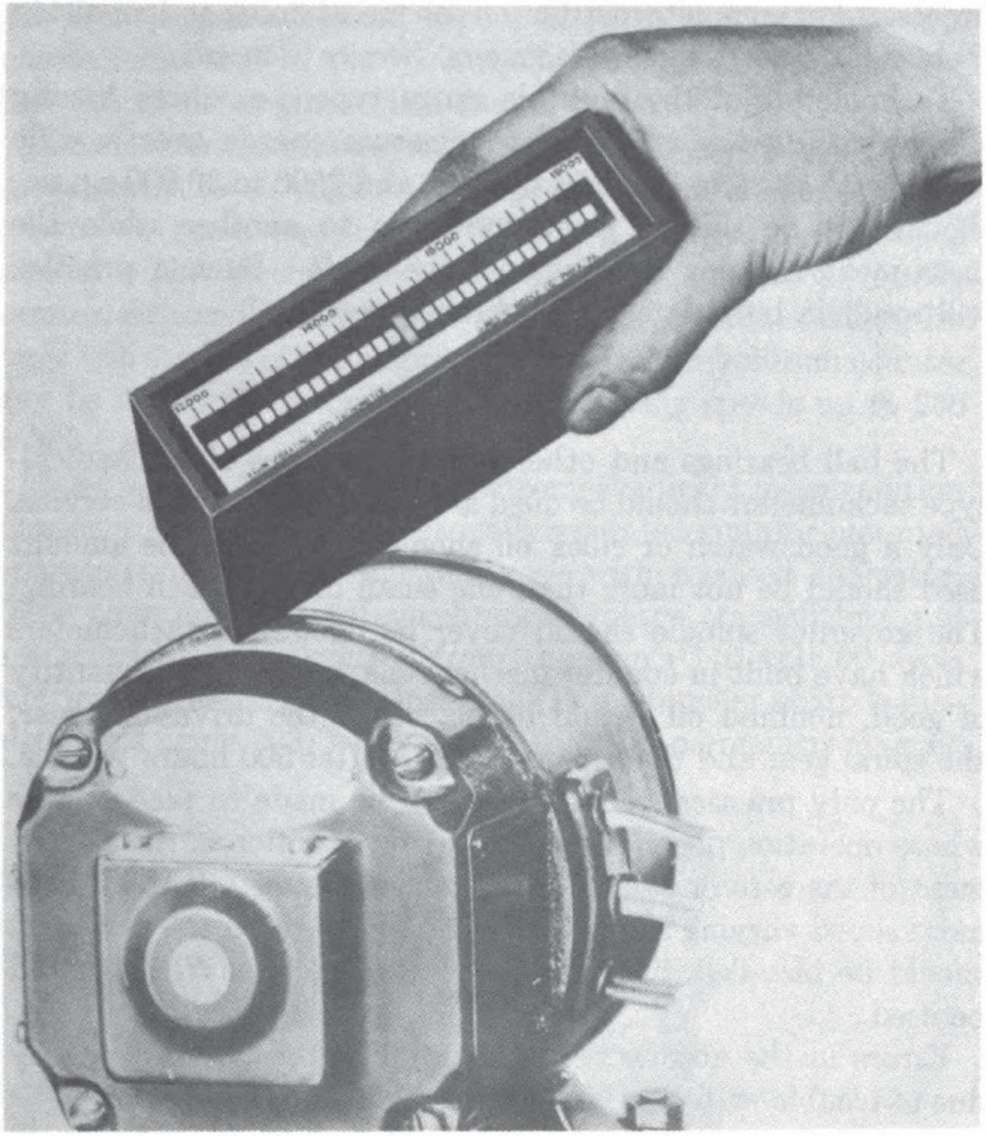


Figure 292. — Frahm vibrating-reed tachometer.

nance tachometer is placed on the foundation casing of the machine whose speed is to be tested, the vibration of the machine sets in resonant vibration the reed nearest its speed.

## Calibration

Direct-reading tachometers are calibrated by comparing the

readings obtained from them with readings obtained by the use of master counters or stop watches. Their calibration is a very delicate operation, involving a full knowledge of the disassembly process. For complete instructions on maintaining and repairing tachometers, see the manufacturers' *Service manuals*.

Tachometers of the multiple range type, i.e., those having sliding ratio gears and used to measure speeds over a wide range, such as 25 to 300, 250 to 3000, and 2500 to 30,000 r.p.m., should not be shifted from one ratio to another while the instrument is being held against the shaft. Such a practice will result in burred gears or a broken gear shaft.

### Maintenance

The ball bearings and other bearing surfaces of mechanical-type tachometers should be oiled after each 500 hours of service. Only a good watch or clock oil should be used. The amount used should be not more than one small drop in each bearing. The governor spindle should never be oiled. In tachometers which have built-in counter mechanisms, a very small quantity of good, nonfluid oil should be placed on the driveshaft gear, the spiral gear and the top cross shaft, after 500 hours' service.

The only practical repairs that can be made to tachometers whose operation depends upon centrifugal action is the adjustment of the zero or stop position of the pointer. If the instrument shows varying errors over the range of the scale, new parts should be installed, if available, or new scale markings should be used.

Errors in the accuracy of the chronometer type are mostly due to trouble with the timing mechanism. This kind of trouble can usually be remedied by an Instrumentman who understands watch repair.

Tachometers not in use should be stowed in a dry place where they will be free from vibration, knocks, and jars.

## REVOLUTION COUNTERS

The distance traveled by a ship can be determined by an exact knowledge of the revolutions made. The number of

revolutions required to make any number of knots is determined by a series of trials over measured courses. The revolution counters commonly used on ships are those of the mechanical and the electromechanical types; they provide a continuous remote indication of the revolutions per minute, and also the direction of the engines when that is desired.

The mechanical-type revolution counter is generally attached permanently to an engine. Its operating arm is connected by a lever to some engine part having a limited reciprocating motion. The instrument is essentially a continuous stroke counter, so constructed that it adds one to the dial reading for every two strokes of the engine. This type of revolution counter may be used satisfactorily on engines having speeds up to 250 or 300 r.p.m.

Many vessels today use the electromechanical type revolution counter, consisting of an electrically operated counter mounted separately or in the same dial case with a speed indicator. These counters have self-synchronous rotary transmitters and motors which are energized from the ship's 110 volt 60 cycle electrical supply. They consist of (1) a propeller shaft transmitter (see figure 293) with a magneto (2) (a permanent magnet

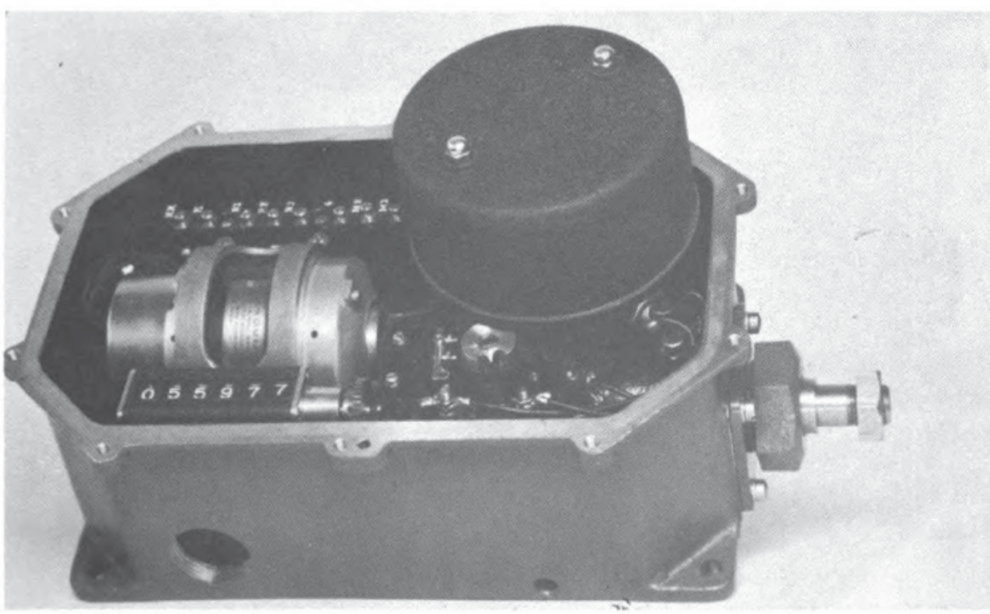



**Figure 293.—Shaft transmitter (cover removed) with vertically-mounted magneto and counter.**

direct-current generator) which generates a small voltage directly proportional to the speed at which it is driven; and (3) a standard electrical measuring instrument of the voltmeter type with the scale calibrated in r.p.m. instead of volts. These machines transmit the rotary motion of the shaft to the counters attached to them, or to the remotely mounted counters and indicators. When they are excited from the ship's electrical supply line and the proper connections are made between the shaft transmitter and the motor, the latter will follow closely any rotary motion given to the transmitter. The effect is the same as though the units of the system were connected by a long flexible shaft.

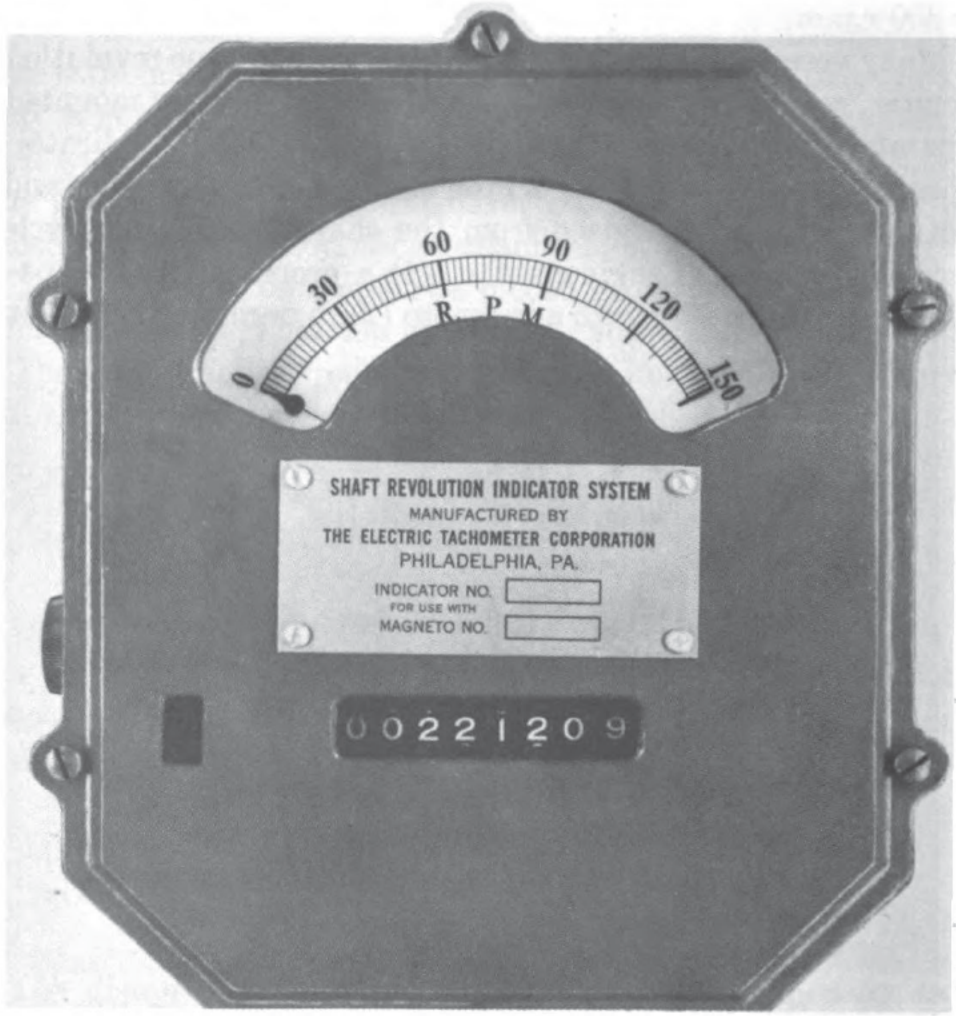



Figure 294. — Indicator unit, with counter.

The indicator scales (see figure 294) are calibrated to show the speed in either ahead or astern revolutions. The shaft transmitter is provided with an automatic unidirectional gear mechanism (a friction-operated reversing switch) which operates the counters so that the indicator is always made to deflect upward and the counters always add, regardless of the direction of the propeller shaft. In this way, astern revolutions are added to ahead revolutions.

The magneto indicator circuit in the transmitter unit is entirely self-contained in operation, and requires no outside electrical power. The indicator line must be energized from the ship's 110-volt 60-cycle electrical supply. (NavPers 10622-A, *Basic Electricity* manual, will inform you on the fundamentals of electricity, and NavPers 10550 *Electrician's Mate, 1 and C*, will explain the theory of the electrical equipment mentioned above.)

## Maintenance

The successful operation of revolution counters depends upon the care that is given them. The working parts of these instruments must be kept covered as much as possible, in order to prevent dust and dirt from settling in the mechanism.

During the period that any revolution counter gear is in operation, its connections must be supplied with a sufficient amount of low-viscosity lubricant. All rotating parts have oil holes or cups for lubrication, and these should be used when the various parts of the mechanism are oiled. The lubricant must be clean and free from foreign matter. External parts subject to erosion should be examined at regular intervals, and if necessary, they should be coated with an approved rust-preventing compound.

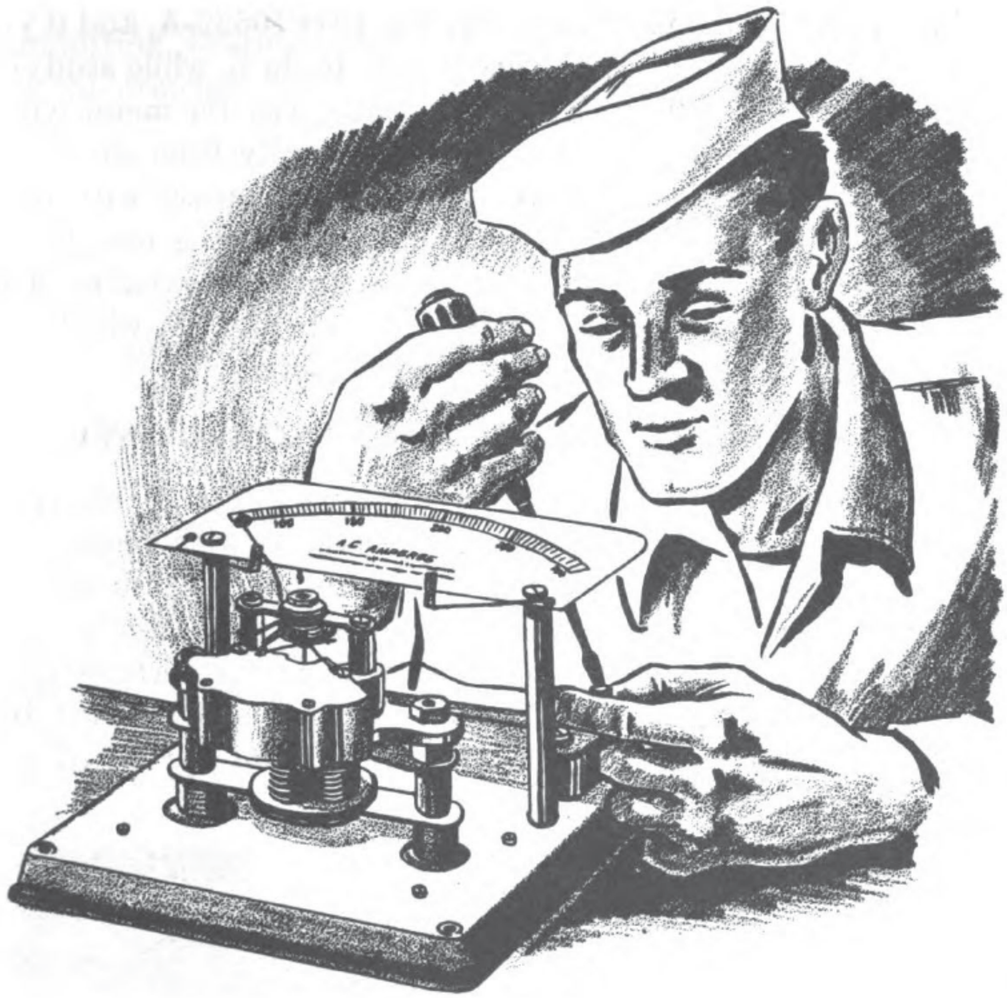
Quarterly, or more often if necessary, the electrical contacts of electrical and electromechanical revolution counters should be examined for oxidation, pitting, fusion and wear. If deep pitting or fusing of terminals makes filing or sandpapering necessary, care must be taken to prevent the filings or particles collecting in other parts of the mechanism.

Running motors and transmitters should have one drop of a good light oil applied to their drive and bearings every six

months (not less). Do not oil the bearings at the slip ring end, as the slip rings and brushes must always be kept clean, bright, and free of oil.

## QUIZ

1. What is the most accurate principle known for measuring pressures?
2. How is the hydrostatic principle used to measure the contents of a tank or reservoir?
3. What is a meniscus?
4. What are the three principal parts of the Pneumercator gage?
5. Explain the principle of operation of the Pneumercator gage.
6. How does the Levelometer gage differ from the Pneumercator gage?
7. Describe the operation of the Liquidometer.
8. What is the operation of a disk-type fluid meter?
9. If you received for repair a disk-type fluid meter which had stopped registering, for what troubles would you look?
10. If a disk-type fluid meter overregisters erratically, what is the probable source of trouble?
11. For what purposes are tachometers used?
12. Describe the principle of operation of the centrifugal-type tachometer.
13. What is the operation of the vibrating-reed resonance tachometer?
14. What is the particular advantage of the vibrating-reed resonance tachometer?
15. How are revolution counters on naval vessels maintained in good operating condition?



# CHAPTER 16

# ELECTRICAL MEASURING INSTRUMENTS

## YOUR ELECTRICAL KNOWLEDGE

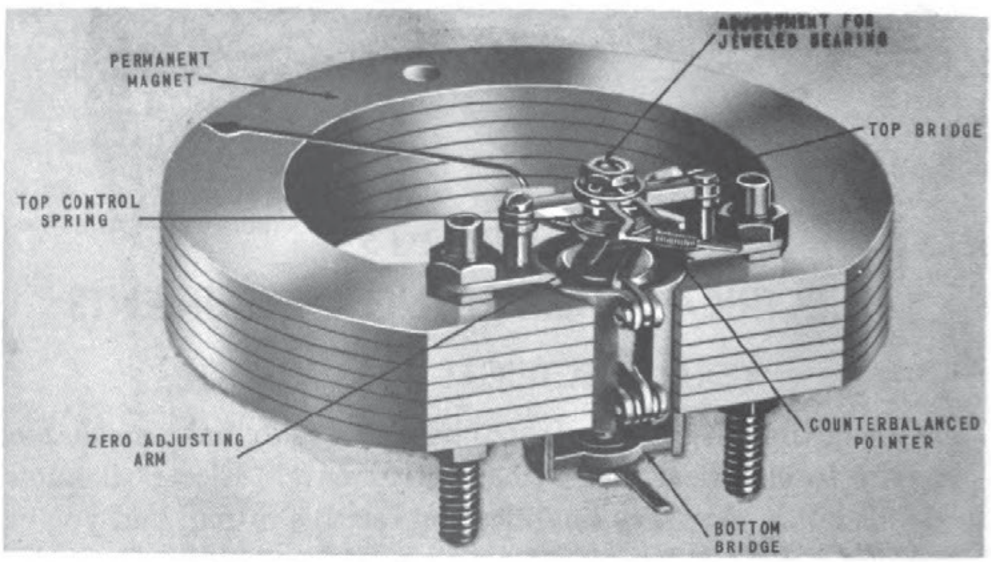
One of the duties of an Instrumentman is to make mechanical repairs to electrical measuring instruments. Electrical knowledge is not a necessary qualification for this rating, and you can become a good Instrumentman without knowing the operating principles of the Navy's electrical meters. But you will become a better Instrumentman, and you will have a keener interest in working on these instruments, if you have a general understanding of electricity.

An excellent book to provide a background for study is the

Navy manual on *Basic Electricity*, NavPers 10622-A, and if you haven't already read it, you should try to do so while studying this chapter. It will explain, for instance, WHY the meter which measures electrical current is made differently from the meter which measures electrical pressure. It will explain WHY magnetism and magnetic fields are important in the design and construction of meters. So read the electricity *Manual* as often as you can, paying special attention to chapter 18, which will introduce you to the theory of electrical meters.

## ELECTRICAL METERS, SWITCHBOARD TYPE

The Navy uses a number of different types of electrical measuring instruments. They are classified with respect to: (1) the electrical quantity or characteristic measured, (2) whether used on alternating- or direct-current circuits, and (3) the type of mounting, such as switchboard or portable type. In some cases, instruments are mounted on a switchboard, but with provision made for removing them from the board and using them as portable meters.




295. — Mechanism of typical permanent-magnet, moving-coil meter.

Electrical measuring instruments usually have the following parts: a moving element with pointer attached, a stationary element (permanent magnet), a controlling element (spring),

mounting, bearings, and a case. The names and arrangement of the principal parts of these meters are shown in figure 295.

## Direct-Current Meters

*D.C. ammeter.* — The ammeter is the instrument that measures the rate of flow of electricity in amperes (the unit of electrical current). The direct-current ammeter is simply a galvanometer composed of a moving coil carrying a pointer which moves over a dial. The permanent magnet inside provides the necessary magnetic field. A spring attached to the moving coil pulls the needle back to zero when no current is flowing through the meter.

Most ammeters have a zero adjustment so that the needle can be set exactly at zero before a reading is to be taken. A shaft with very hard pivot points is used to carry the movable element. The pivot points are fitted into the highly polished jewels or hard glass bearings of the moving element, allowing the moving element and pointer on it to rotate with very little friction.

When a steady current flows through the moving coil, a magnetic field is set up, causing the coil to rotate and to move the pointer over the graduated scale. This direct-current meter cannot be used for measuring alternating current, because the deflecting force of alternating current changes direction too rapidly to allow movement of the pointer.

A direct-current ammeter made for switchboard mounting is illustrated in figure 296.

*D.C. voltmeter.* — The ordinary direct-current voltmeter is really an ammeter with a high resistance inserted in its circuit. The voltmeter measures the circuit's voltage in volts (the unit of electrical pressure). The high resistance in its circuit limits the current to a value that will fall within the full-scale deflection of the pointer when the voltage is applied.

## Alternating-Current Meters

Ammeters for use on alternating-current circuits may be either the moving-iron repulsion-vane type, or the electrodynamometer type.


Figure 296. — Direct -current ammeter, for switchboard mounting

*Moving-iron type.* — In the moving-iron type ammeter, one or several pieces of soft iron or magnetic alloy are caused to move by the magnetic field of a fixed coil carrying the current to be measured. The like poles of the fixed coil and the moving vane repel each other; the resulting force tends to turn the vane. The value of the current flowing through the meter is indicated by the position of the pointer. The distance that the pointer moves up the scale depends upon the amount of current going through the fixed coil.

Alternating-current meters do not depend for their operation on permanent magnets, since every reversal of the current reverses the polarity of the coil. The pointer would merely flutter with alternating current, instead of moving steadily over the instrument's scale.

The switchboard-type alternating-current voltmeter of the

moving-iron repulsion-vane type is similar in appearance to the switchboard mounted direct-current ammeter. The pointer of this voltmeter is brought to rest quickly by a damping device. A small aluminum disk mounted on the shaft of the moving element turns between the poles of a permanent magnet. The motion of the disk between the poles of the magnet sets up currents in the disk. These create a magnetic field that interacts with the field of the magnet and opposes the motion of the moving element, resulting in a *drag* on the disk which tends to stop it. Most alternating-current ammeters are of the moving-iron repulsion-vane type.

*Electrodynamometer type.* — The other kind of alternating-current meter is that known as the electrodynamometer type. This meter consists of two coils connected in series; one coil is fixed and the other is movable, and the current passes through both of them. The movable coil is mounted on jeweled bearings in the magnetic field of the fixed coil. The force exerted by the magnetic field of one coil on the current flowing in the other coil turns the moving coil.

*Wattmeter.* — The wattmeter, so called because it measures electrical power in watts or kilowatts, is constructed like the electrodynamometer voltmeter except that its coils are connected separately instead of in series. That is, the moving coil is connected as in a voltmeter, while the fixed coil is connected as in an ammeter. The wattmeter, then, is really an ammeter and a voltmeter combined.

The magnetic field set up by the moving coil is proportional to the voltage, and the magnetic field set up around the fixed coil is proportional to the current. The action of these magnetic fields on each other turns the moving coil and the pointer attached to it. The movement of the coil and needle is therefore proportional to the power, since electrical power equals voltage multiplied by current. The wattmeter operates on either alternating or direct current.

## ENERGY MEASURING INSTRUMENTS

*Watt-hour meter.* — The watt-hour meter measures the work done by electrical energy, or the amount of electrical energy

expended. This meter is basically a small motor connected by reducing gears to the pointers on a series of dials. The speed of rotation of the dials is proportional to the amount of electrical energy used. Watt-hour meters are made for use on both alternating-and direct-current circuits.

Watt-hour meters are not provided in naval vessels of recent construction, but they will be received for repair from the older ships.

## CIRCUIT CHARACTERISTIC MEASURING INSTRUMENTS

In all ammeters, voltmeters, and wattmeters, the deflecting force exerted by a magnetic field on a moving coil is balanced against a restoring force produced by a spring. When the power is cut off, the spring returns the moving element to a zero position.

The instruments described below have no spring control. The value of the electrical characteristic desired is indicated by the position of the moving element when a balance is reached between several opposing forces inside the meter. One of these forces takes the place of the spring. If the power is cut off, the moving element of these meters can come to rest AT ANY POSITION on the dial within its range of travel.

*Frequency meter.* — When the voltage in an electrical circuit increases from zero to a maximum point, then decreases through zero to a maximum point in the opposite direction, then returns to zero again, a CYCLE is said to have been completed. The number of cycles occurring per second is called the *frequency.* The most common frequencies used in this country are 60 cycles and 25 cycles. The 25-cycle frequency is less commonly employed, mainly because it produces a noticeable flicker when it is used for lighting circuits. The meter which indicates the frequency of an alternating current circuit is called a frequency meter. Any change in frequency of the circuit will affect the magnetic fields inside the meter and make its moving element deflect; there is a different position of the pointer for each frequency. A frequency meter is illustrated in figure 297.

*Power factor meter.* — In alternating-current circuits, the

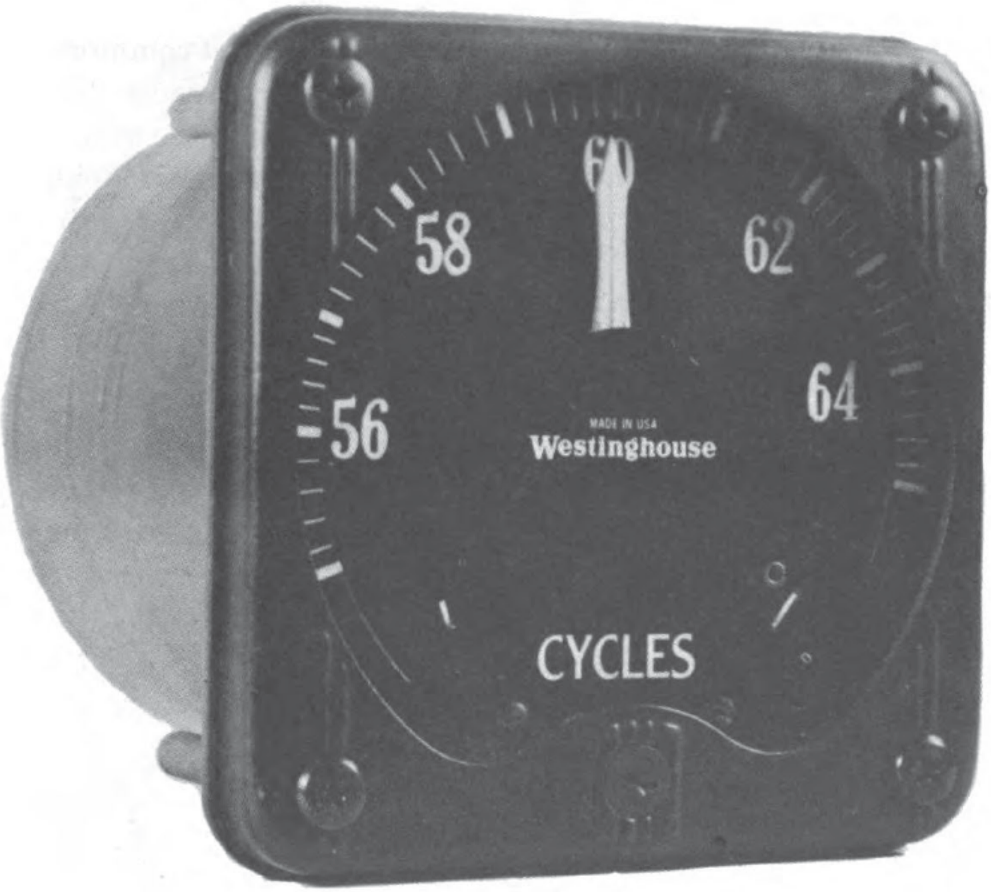



Figure 297. — Frequency meter.

power flowing in the lines is made up of two component parts: useful power, which is expended in the load, and power which flows back and forth and contributes to the load but is otherwise wasted. The ratio of the useful power to the total power in the circuit is called the POWER FACTOR. (If you want to study more about power factor in electrical circuits, see page 215 of *Electrician's Mate 2*, NavPers 10549.)

*Synchroscope.* — A synchroscope is an electrical meter which indicates the frequency and voltage conditions in an alternating-current circuit on which one or more generators are running. The synchroscope is needed when another generator is to be connected with the same line. In design and construction, it is very similar to the power factor meter.

## ELECTRICAL METERS, PORTABLE TYPE

The portable electrical measuring instruments most commonly used in the Navy are ammeters and voltmeters. Since they are constructed to give more accurate readings than the switchboard meters and are not subject to stray magnetic fields, portable meters are used as secondary standards to check the accuracy of switchboard meters. They are also used for general testing purposes whenever current or voltage measurements are needed on isolated portions of electrical circuits.

### Direct-Current Portable Meters

A typical portable direct-current voltmeter is shown in figure 298. This particular meter has four terminals, allowing readings of any one of three different scales. In general, the mechanisms inside these portable instruments are similar to those of the switchboard meters.

### Alternating-Current Portable Meters

As previously stated, most alternating-current ammeters and voltmeters employ the moving-iron, repulsion-vane mechanism. A portable ammeter of this type is similar in appearance to the portable direct-current voltmeter.

*Electrodynamometer.* — The electrodynamometer type movement is employed in portable meters that measure electrical power and indicate the frequency, power factor and other characteristics of alternating-current circuits. The exterior appearance of this meter is the same as that of most other portable meters of this type.

*Split core ammeter.* — Split core ammeters are portable instruments that use the magnetic field around a current-carrying electrical conductor to produce a deflection of an indicating pointer. These meters are widely used on Navy ships for trouble-shooting and maintenance work. A magnetic coupling between the magnetic field and the indicating pointer is obtained simply by clamping a split magnetic core around the conductor. The split core is hinged, and can readily be clamped around a conductor without breaking any electrical

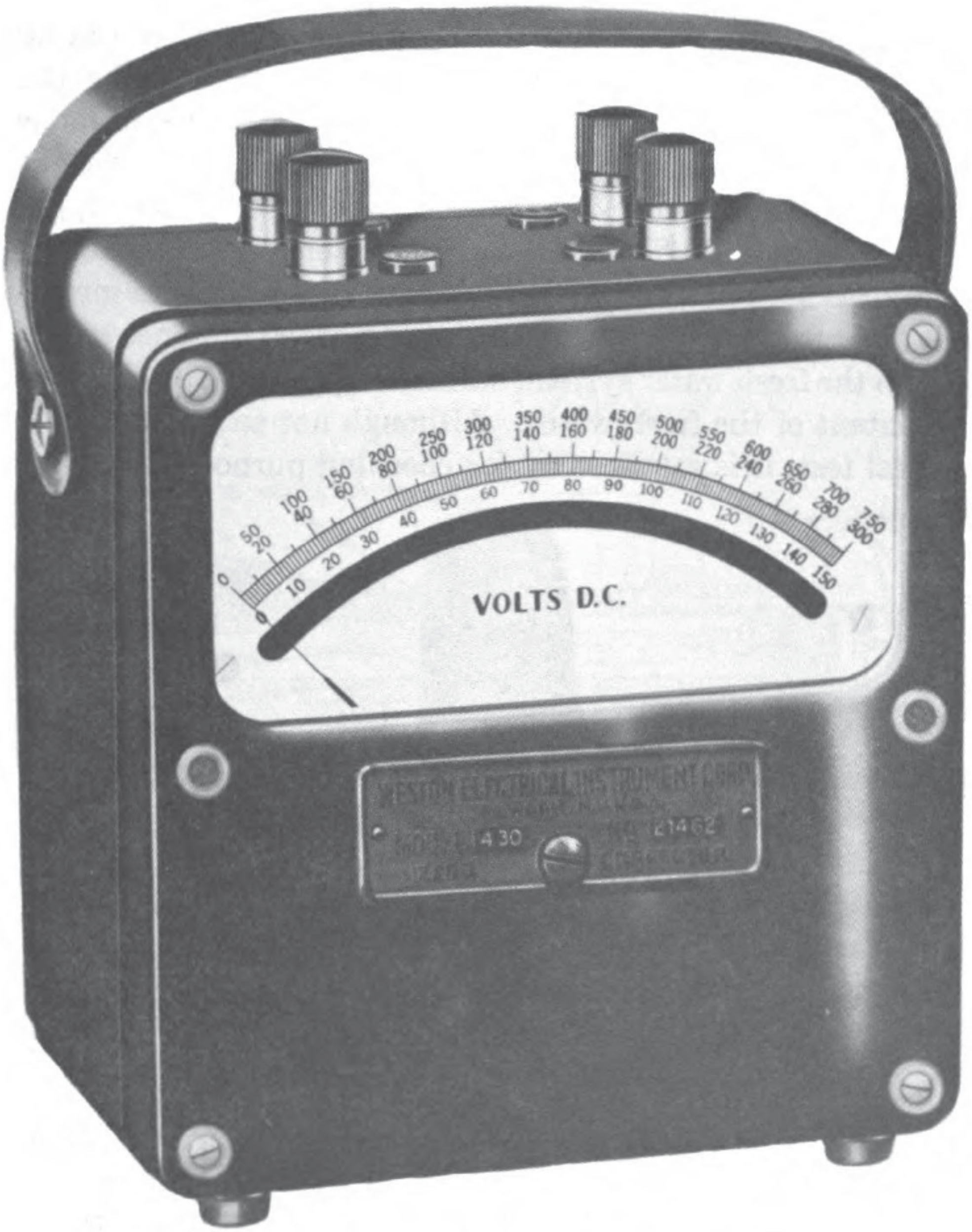



Figure 298. — Direct-current voltmeter, portable type.

connection. These meters operate on either direct- or alternating-current circuits. A meter of this type is illustrated in figure 299.

## SALINITY INDICATORS

Since sea water is used on board ship in condensers and

evaporating plants, there is always the possibility that it may contaminate fresh water stored in adjoining tanks. Locating salt water leaks and preventing salt water from reaching the boiler feed water is an important matter. Once the water is seriously contaminated, the ship cannot long continue efficient operation. Routine chemical tests for ships' fresh water supply are prescribed in *BuShip's Manual*, chapter 87. The salinity indicator is used as a *supplement* to these tests. It is an instrument designed to give immediate warning of the presence of salt water in the fresh water system, and to indicate the approximate salt content of the fresh water. Although not so accurate as a chemical test, it is satisfactory for checking purposes.

**Figure 299. — Split core ammeter.**

The salinity-indicator system operates on the principle that the electrical conductivity of water varies with its chemical impurity content. By putting a cell consisting of two electrodes of opposite electrical polarity in the fresh water, a fixed resistance is obtained when an electrical voltage is impressed upon the system (assuming that the impurity content and the water temperature remain the same). The resistance is read on a meter-type indicator graduated in grains of chlorine per gallon. If the salt content of the water increases, as happens when sea water leakage occurs, the conductivity between the electrodes increases and the indicator pointer moves upward in proportion,

providing the man on watch with a warning before a dangerous condition is reached.

Salinity indicator cells (see figure 300) are located aboard

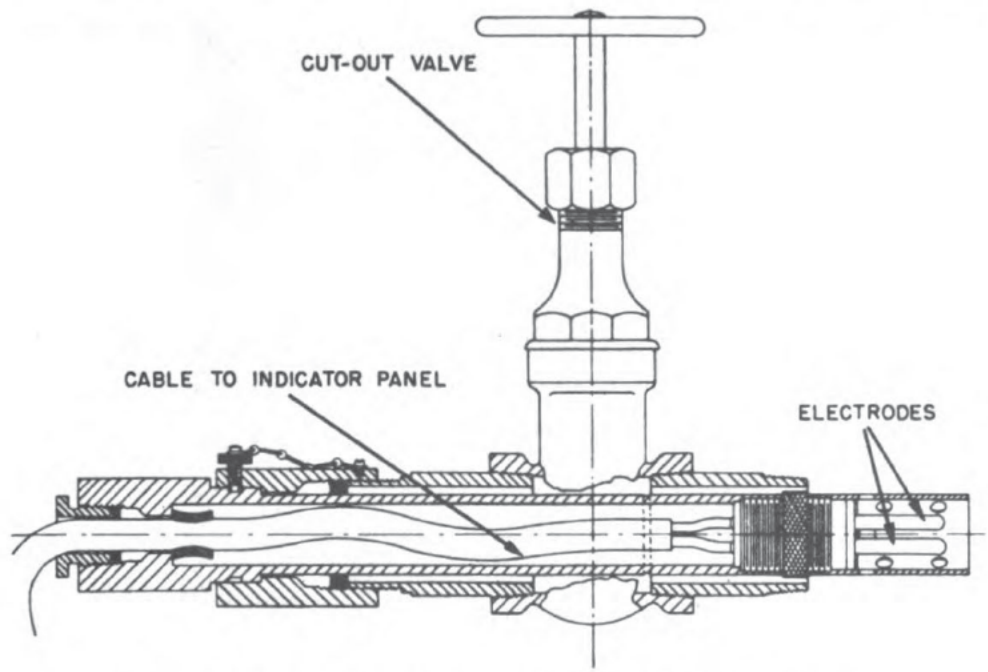



Figure 300. — Salinity indicator installed in boiler feed system.

ship in such places as the main and auxilliary condensate lines from each condenser, the nest drains of distilling plants, fresh water pump discharge lines, and distiller air ejector drains. A temperature compensator is used to adjust the instrument so that it will correct for variation between the existing temperature of the water and that at which the indicator was calibrated. Each cell is a unit within itself and is installed in a system to be tested. It is therefore possible to obtain multiple readings with a single dial indicator, simply by turning the selector switch to connect the indicator to the system under consideration. The indicators and the rotary selector switches for selecting the cell to be used are located at main engine control stations and on distilling plant instrument boards. (See figure 301.)

## METER MAINTENANCE

Since electrical meters are delicate and expensive instruments,

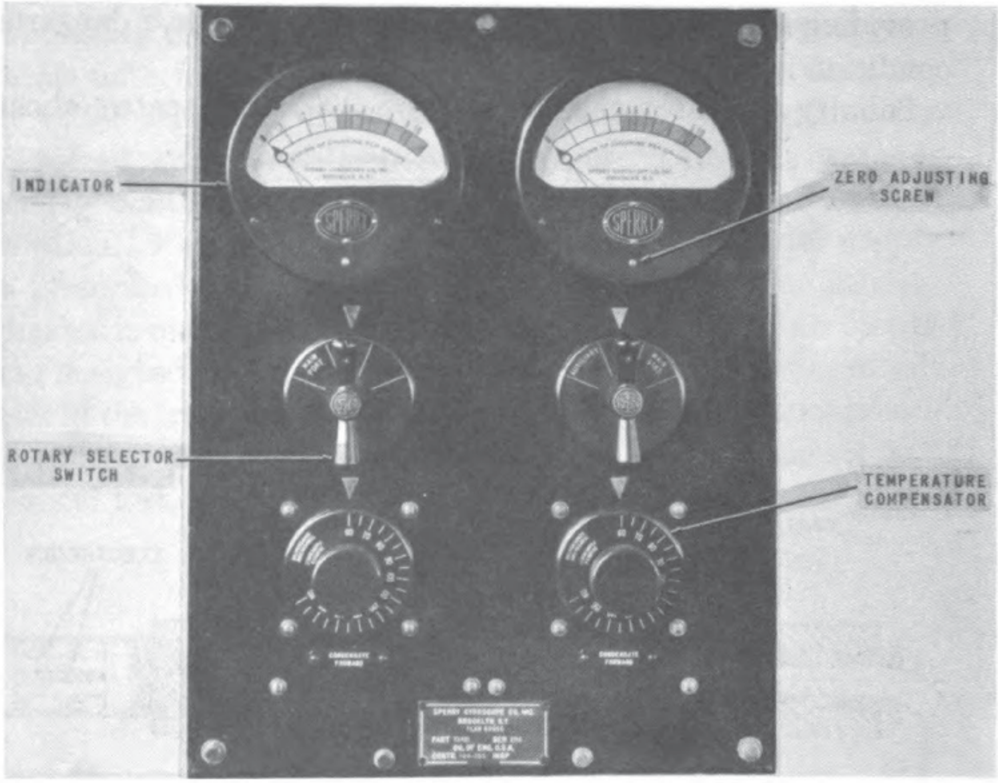


Figure 301. — Salinity indicator panel.

great care must be taken in handling and repairing them. Always have all the needed repair tools on hand, and use each tool for its specific purpose. Keep the meters clean and free from dust inside. Dust or dirt on the jewels or pivots will cause extra friction, resulting in excessive wear and end play in the moving parts.

Use a soft-bristle brush to brush each of the disassembled electrical meter parts, then wipe them carefully with a lint-free cloth before reassembling them. Carefully dry each part, and the meter case. Moisture and corrosion cause a great deal of trouble in the functioning of electrical meters, and especially in the smaller panel instruments. Be careful not even to breathe on any part of the mechanism, since rust and corrosion will inevitably result.

## Repair Procedures

When you receive an electrical meter for repair, first check it over for the following mechanical troubles:

1. Case or glass broken.

2. Pointer bent.

3. Missing nuts or screws.

4. Loose terminals.

In repairing these faults, follow the procedures given below:

*Replacing broken glass.* — Clean the meter thoroughly with a damp cloth to prevent dust from getting into the movement. (Cleaning with *dry* cloth may induce a STATIC charge on the glass, and affect the instrument reading.) Take out the case screws and lift the mechanism out of the case. Make sure that all broken glass is removed from the meter, and then install a new glass.

*Repairing the zero corrector.* — If the outside screw that adjusts the zero corrector is broken or missing, take off the case and install a new screw.

*Broken or cracked case.* — Replace with a new case.

*Missing bolts and nuts.* — Be sure that all bolts and nuts have been replaced and are tight in their connections, before a repaired meter leaves the shop.

*Damaged terminal studs.* — Rethread the old terminals if possible; otherwise, replace the entire base assembly.

When disassembling an electrical meter in order to make repairs on its mechanism, always follow this procedure:

1. Take the movement out of the case.

2. Remove the dial screws and then slide the dial out from under the pointer, taking care not to bend the pointer.

3. Unscrew the movement and permanent magnet from the base.

4. Unsolder the control springs (top and bottom), and other soldered connections.

5. Remove the screws from the top and bottom bridges.

6. Remove the top bridge and lift out the moving-element coil.

7. Place a soft iron bar or "keeper" over the air gap of the permanent magnet.

8. Clean and dry each part thoroughly.

## Diagnosing Troubles

Electrical meter troubles fall into two broad classes: failure of the meter to indicate, and failure to indicate correctly.

Failure of the meter to indicate could be caused by any one of the following mechanical troubles:

1. A sticking pointer.
2. Element jarred (out of jewels).
3. Pivots too tight in jewels.
4. A sticking damping-vane.
5. Damping disk touching magnet.
6. Broken pivots.
7. Coils sticking, due to foreign matter between coils.
8. Coils warped out of shape.
9. Loose wires.
10. Coil cement on control springs or in air gap.
11. Cross-arms caught on nearby parts.

If the meter indicates, but gives an incorrect reading, check for the mechanical trouble listed below:

1. Static or rolling friction of moving element.
2. Pointer stalls in up-scale position.
3. Movement out of balance.
4. Control spring coils touching.
5. Loose or bent pointer.
6. Zero reading shifts.
7. "Set" control springs.
8. Loose spring connections.
9. Loose pivots.
10. Loose jewels.
11. Pointer not operating full scale.
12. Too much or not enough end play.
13. Dial or element shifts.
14. Coils rubbing.
15. Damping-vane rubbing.
16. Tail-weight hitting zero-adjustment pin.
17. Pointer touching dial or glass.
18. Pointer shaft touching coil.
19. Damping disk touching stationary magnet.

20. Moving-element shaft touching damping-chamber cover (air damping meter).

## Adjustment Procedure

The correct methods of meter adjustment and repair are given in the following paragraphs:

*Balance weight adjustment.* — The balance weights (the split thread, wire-wound or lock-nut weights on the pointer shaft) of the moving element are essential for accurate scale readings. When the meter is in normal position, the pointer must be resting at zero. If not, several steps must be taken to make this adjustment. First, check the balance weights to see if the pointer rests at zero when the meter is in normal position, but moves off zero as the meter is turned clockwise through 360 degrees. If the pointer moves off zero during this motion, then the moving element is out of balance. In such a case, check the position of the pointer at each quarter turn for its maximum deviation from the zero position, and balance the moving element each time by adjusting the balance weight until the pointer is restored to the zero position. The correct working position for making this balance weight adjustment is illustrated in figure 302. The correct size balance wrench should always be used for adjusting the split-thread weight. See that weights of this type are compressed just enough so that, properly adjusted, they will grip the shaft tightly enough to prevent shifting but not tightly enough to cut a thread into the shaft.

The most widely used balance weight is the wire-wound type, usually consisting of a bronze wire that has first been wound on a slightly curved arbor to give it gripping strength. (See figure 295.) To avoid damaging balance weights of this type when making adjustments, grip the entire length with a pair of flat-surfaced tweezers and turn it in the desired direction. Never pull or push this weight, because to do so would stretch it and change the distance between turns, altering the calibration of the meter.

The locknut balance weight has, near the end of the nut, several threads that are smaller than the threads on the shaft. Do not use force in moving this type of weight, as that might

damage the threads and result in later shifting of the weight under vibration.

Since these balance weights are hexagonal in shape, use a balance wrench of that type when making adjustments. *Never cement or solder balance weights to the shaft.*

*Zero pointer adjustment.* — After the balance weights have

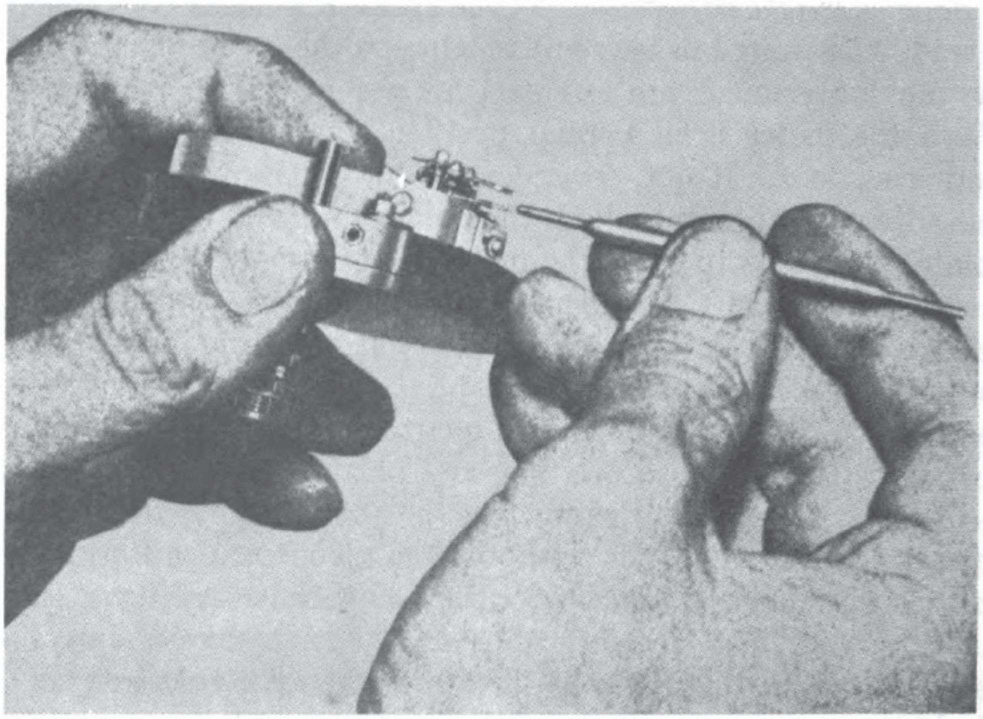


Figure 302. — Adjusting a balance weight.

been adjusted, the pointer can be set to zero either by shifting the lower control spring adjuster, or, in the case of two-piece adjusters, by moving the slip-ring collet on the shaft, thus shifting the top or spring contact side.

To shift the lower control spring adjuster, grasp its end with a pair of tweezers at the point where the spring is soldered to the adjuster, and move the arm either upwards or downwards until the pointer rests at zero. To shift the top or spring contact side of a two-piece adjuster, loosen the nut (using a small wrench if necessary) that holds the control spring and the lower adjustment arm. Holding the upper spring holder in the center position, with a pair of tweezers move the lower spring holder

until the pointer rests at zero. *Be careful not to bend the control springs.*

If the pointer has moved from its zero position after the movement has been inserted in the case, the necessary correction can be made by turning the external adjustment screw. The zero adjustment should not be used in an attempt to correct for a bent pointer.

*Pivots.* — The pivots used in modern meters are made of hardened and polished steel, and are usually mounted on the

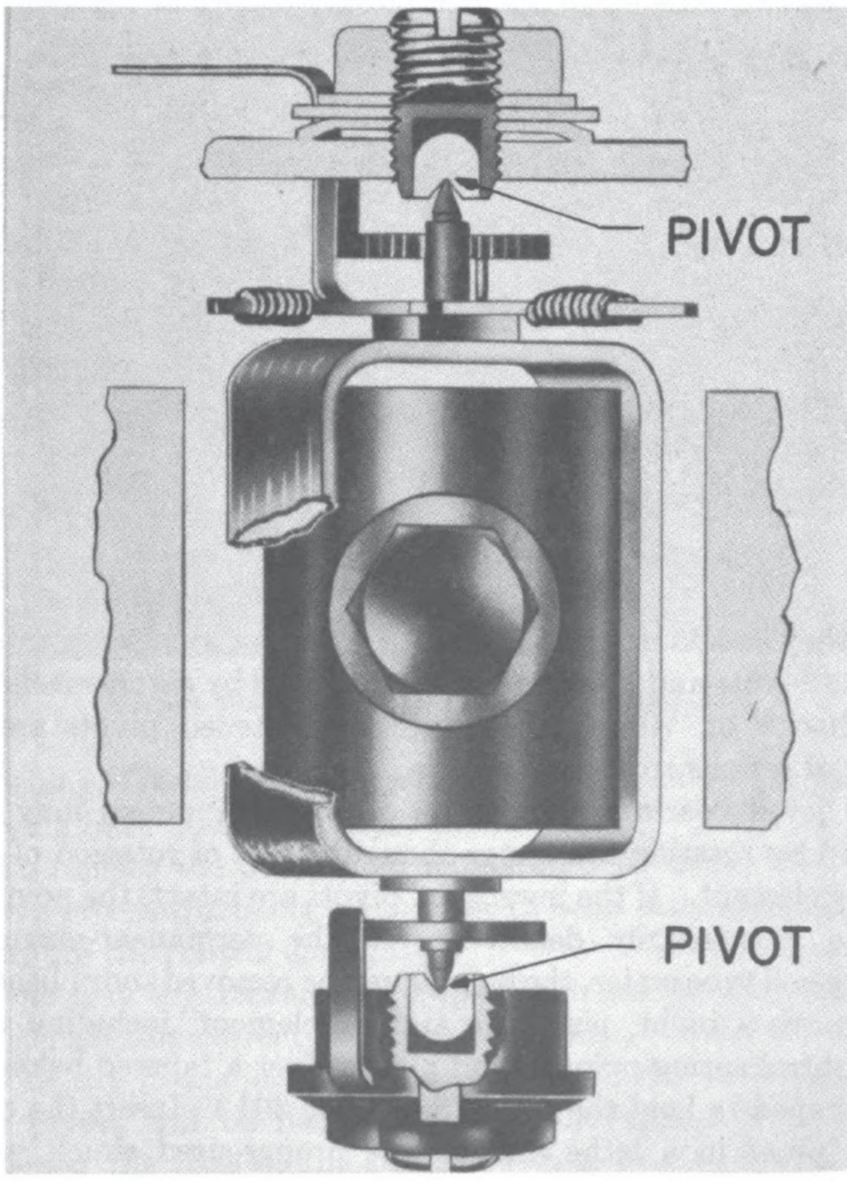



Figure 303. — Standard pivot arrangement in electrical meters.

outside of the moving coil (see figure 303.) They are shaped to fit into the jeweled bearings with a minimum of end play or side play. Although they are capable of withstanding considerable

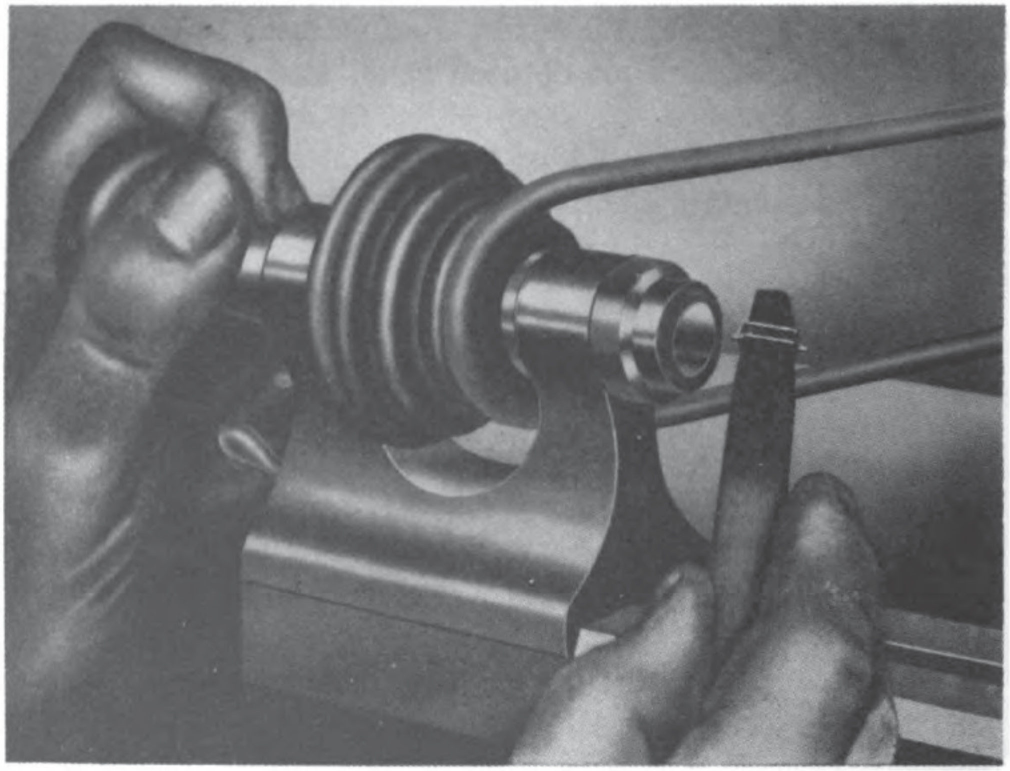


Figure 304. — Removing pivot from meter movement.

wear, they should always be handled carefully when undergoing repair. Pivots and jewels are often damaged by severe mechanical shocks or vibration. Rough or flattened pivots are a source of serious trouble in meters.

The jewel bearings and pivots of portable meters may be checked by rotating the meter about the axis of rotation of its moving element. If the jewels and pivots are intact, the pointer will be momentarily deflected. In the permanent-magnet, moving-coil type meter, the pointer can be removed and polished. To remove a pivot, place the moving element, including the coil, control spring pointer, and pivots, over a tapered bakelite stick shaped to hold the coil. (See figure 304.) Insert the end of the pivot in a lathe holding the proper-sized chuck, and slowly turn the lathe by hand until the pivot is tightly held.

Then, continuing to turn the lathe by hand, gently pull straight away on the bakelite stick, causing the pivot to pull out of the pivot base. The pivot can be removed from the chuck with a pair of tweezers, and then inserted in reverse. An India or Arkansas polishing stone (see figure 305) may then be used to polish the end of the pivot while the lathe is slowly turned by hand. Use jewelers' rouge or diamantine to complete the

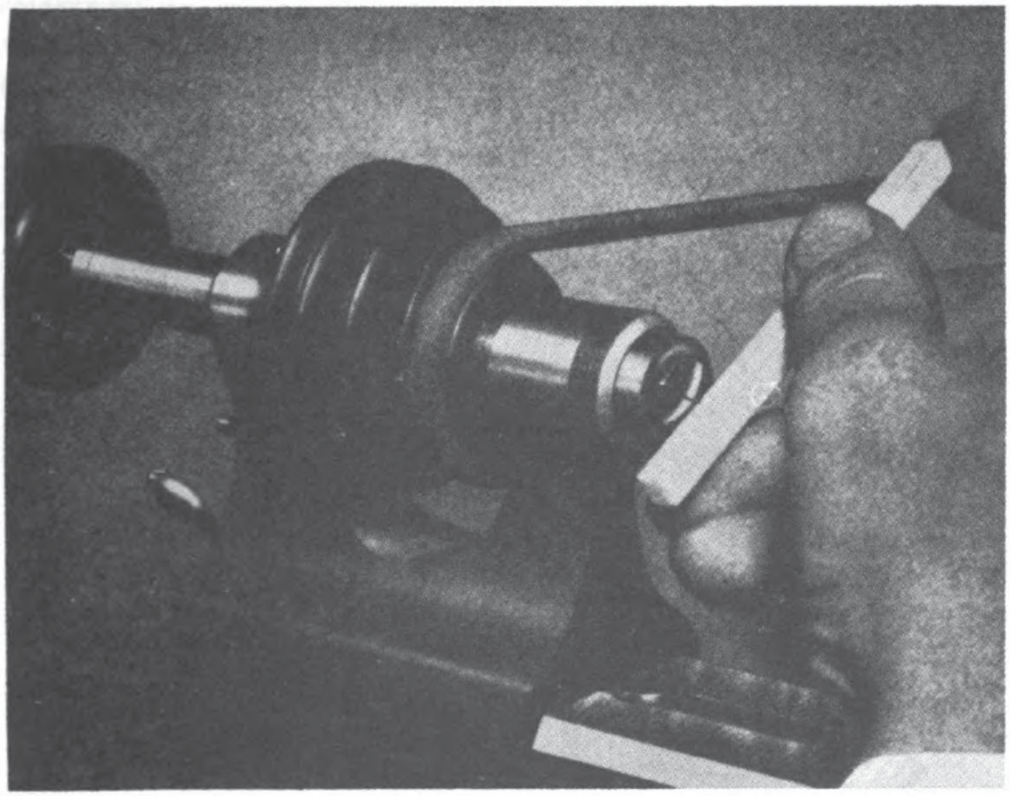


Figure 305. — Polishing the pivot with polishing stone.

polishing. *Never hold the polishing stone stationary.* Keep it moving back and forth under the pivot.

To replace the pivot after it has been polished, reverse the above procedure, being careful not to bend the damping coil or to injure the control springs.

*End play adjustment.* — To operate properly, the pivot shaft must have the correct amount of end play. If the pivot is set too tightly in the jewel, the pointer action will be sluggish and the pivots will be flattened. Test the end play by gently grasping the base of the pointer with a pair of tweezers and

moving the element up and down. If this test indicates too much end play, use a jewelers' screwdriver to tighten the screws holding the jewel until the amount of end play is correct. Experience will teach you to recognize the proper end play for a meter.

*Jewels.* — When inspecting jewels for cracks or breaks, use a jeweler's loupe. Use a soft-bristle brush to remove dust, and with a needle remove any encrusted dirt. Cracked or broken jewels should be replaced with new ones.

The jewels (figure 306) used in meters are made from sapphires

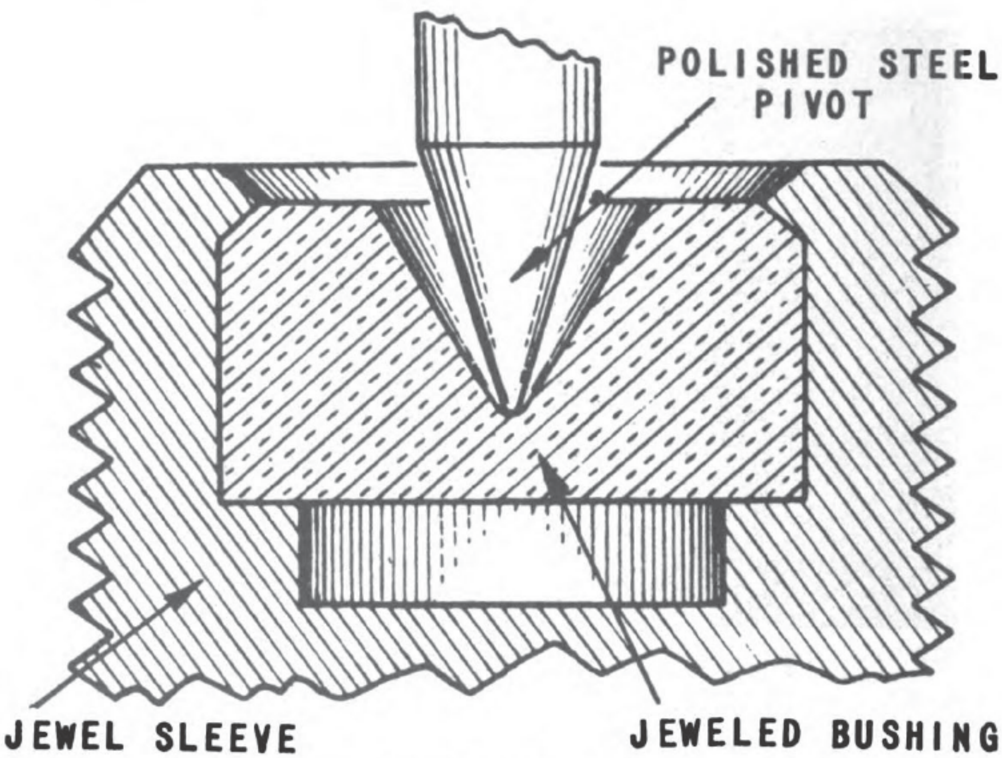



Figure 306. — V-jewel meter bearing.

or from hard, highly polished glass, with V-shaped holes to accommodate the cone-shaped pivots. The jewels in meters should never be oiled.

*Control springs.* — The control springs used in meters are usually made of bronze alloy, rolled to the correct size and heat-treated to relieve internal stresses and to retain their shape in service. However, springs must be handled very carefully

during servicing. In most cases, the inner end of the spring is soldered to a collet on the shaft of the moving element, while the outer end of the spring is soldered to the upper end of the zero regulator.

When installing a new or repaired control spring, clean the surfaces thoroughly and cover the spring's end with a small amount of nonacid, noncorrosive soldering flux. The soldering iron must be hot enough to make the solder flow freely. Be careful not to hold the iron in contact with the spring for too long a time, as that would anneal it at the point of contact, and thus cause uneven elasticity. When the soldering operation is completed, wash the joint with a good cleaning solution, such as pure grain alcohol, to remove any remaining soldering flux or grease. Always be careful not to strain any of the coils when soldering a spring.

If the coils of a new spring must be straightened or bent, make the radius of the bends as large as possible (see figure 307).

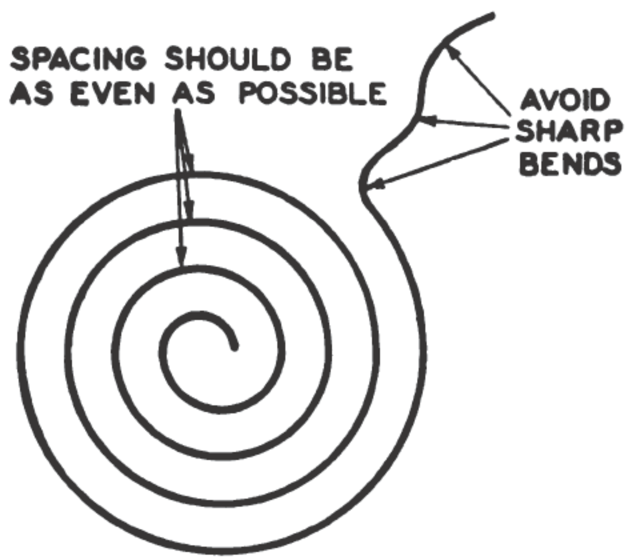



Figure 307. — Shaping control springs.

The coils of the spring should be made as evenly as possible, since uneven coils may touch each other when the spring is compressed, causing incorrect scale readings.

When the adjustments in a spring have been completed, run the pointer up-scale to see whether any of the coils touch each

other. Notice also whether the spring touches any nearby parts during this test operation.

When electrical motors are not in use they should be stowed where they will be free from dust, oil, heat, moisture, and excessive vibration. A closed cabinet makes a good stowage place for these instruments.

## ELECTRICAL REPAIRS

You will not be required to make any electrical repairs to electrical measuring instruments. Calibration of meters, testing and replacement of electrical parts and any other electrical repairs that may be needed, will always be made by an Electrician's Mate.

## QUIZ

1. When you receive an electrical meter that needs mechanical repairs, for what minor mechanical troubles would you first look?
2. In which two broad classes do electrical meter troubles fall?
3. Name six common mechanical faults in an electrical meter which would make it fail to indicate.
4. Name six common mechanical faults in an electrical meter which would make it indicate but give an incorrect reading.
5. How can the condition of the jewel bearings and the pivots in portable electrical meters be easily checked?
6. Which precautions must always be considered when repairing the control springs in electrical meters?

# APPENDIX I

# ANSWERS TO QUIZZES

## CHAPTER 1

## AFLOAT AND ASHORE

1. The duties of the Instrumentman are to install, test, calibrate, overhaul and repair mechanical instruments such as watches, clocks, typewriters, other office machines, gages and meters, and to repair the mechanical parts of electrical meters.
2. The Instrumentman usually works on repair ships, but occasionally he may be assigned to a naval shipyard instrument repair shop.
3. The Instrumentman usually works in the repair department.
4. The Instrumentman does have some military duties.
5. The Instrumentman can learn about his military duties by reading NAVY REGULATIONS and GENERAL TRAINING COURSE FOR PETTY OFFICERS, NavPers 10602 A.

## CHAPTER 2

## TIMEKEEPERS — OLD AND NEW

1. The first timekeeper was the sundial, used by the Babylonians before 2000 B. C.
2. The second timekeeper was the clepsydra, or water clock, which measured the hours at night as well as by day.
3. The mainspring, invented about the year 1500 by Peter Henlein of Nuremberg, made the modern pocket watch possible.
4. The invention of the pendulum in 1658 revolutionized the construction and accuracy of clocks.
5. The invention of a really accurate timepiece, later called the chronometer, made it possible for navigation to become almost an exact science.
6. The four major parts of a watch are: (1) the driving mechanism, (2) the transmitting mechanism, (3) the controlling mechanism, and (4) the indicating mechanism.
7. The balance and hairspring unit has been called the *brain of the watch*.
8. The barrel turns about 5 times before the watch runs down.

9. The barrel rotates about once every 8 hours, making the modern watch run about 40 hours.
10. The escape wheel usually has 15 teeth and makes 600 turns per hour.
11. The escape wheel transmits energy to the pallet, causing it to rock back and forth on the pallet arbor; the pallet fork moves the jewel pin, which in turn moves the impulse roller (to which it is rigidly fastened) and thus causes the balance wheel to vibrate.
12. Elinvar is a nickel-steel-chromium alloy which is almost insensible to temperature changes, thereby enabling the watch to keep better time.
13. Jewels are used in watches and clocks to reduce friction and so add to the accuracy of the watch.
14. The term *R* stone stands for receiving stone, or receiving pallet, and the term *L* stone stands for let-off or discharging pallet.
15. The cannon pinion, so called because of its similarity in shape to a cannon, carries the minute hand and turns completely once an hour.

# CHAPTER 3

## WATCH REPAIR TOOLS

1. The 3-power size and 10-power size loupes are commonly used in watch repair.
2. Screw drivers are usually held in the vertical position in watch repair.
3. The tool generally used by watch repairmen to measure diameters and thicknesses accurately is the metric micrometer caliper, commonly called "the mike."
4. The Arkansas stone is a smooth natural oilstone used for sharpening gravers, screw drivers and other tools to a final finish.
5. The needle gage is a thin graduated scale with a plunger-type tapered needle at one end, used to measure the size of jewel holes.
6. The watch repairman uses the micrometer caliper more frequently than the vernier caliper because the micrometer caliper is more accurate.
7. The square nose pliers are most commonly used in watch repair.
8. The speed of a jeweler's lathe can be reduced without overheating the motor by using a countershaft.
9. Staking is the operation of rigidly fastening the balance wheel of a watch to the balance staff.
10. Truing in the flat is the operation of leveling the rim of a balance wheel until all parts of the rim lie in the same plane, and the entire rim is perpendicular to the staff axis.
11. Truing in the round is the operation of bending the rim of a balance wheel uutil it is concentric with the staff axis.
12. Poising is the operation of adjusting the balance wheel of a watch so as to eliminate the effect of gravity.

13. The friction jewel tool usually consists of a lever device, a set of reamers, a set of pushers and an assortment of stumps.

## CHAPTER 4

## CLEANING AND OILING WATCHES

1. The two methods of cleaning watches in common use today are the machine cleaning method and the hand cleaning method. The Navy prefers the machine cleaning method.
2. The machine method is both faster and easier.
3. The four precautions that should always be taken when cleaning watches are:
   a. Handle the parts with tweezers only.
   b. Be sure that the cleaning solution has fully evaporated from every part before reassembly.
   c. Inspect all parts for particles of pith or pegwood before reassembly.
   d. Always use the mainspring winder to insert the mainspring into the barrel.
4. A watch should be cleaned and oiled at least every 12 months.
5. The three main classes of oils are: mineral oils, animal oils, and vegetable oils.
6. Mineral oils stay fresh for a long time, but they do not stay where they are placed; that is, they spread.
7. Animal and vegetable oils stay in the desired position, but they dry rather rapidly and become thick and gummy.
8. In commercial practice, mineral, animal, and vegetable oils are mixed together in varying proportions to produce a fairly satisfactory product for oiling watches.
9. The dial train wheels, the hairspring, the teeth or pinions of the center, third, and fourth wheels, and the roller jewels should never be oiled.
10. Watches and clocks aboard ship should be left in their original cartons and stowed in a dry place protected from extreme heat or cold.

## CHAPTER 5

## WATCH CASUALTY ANALYSIS

1. The six basic operations of watch repair are: (1) inspection before disassembly, (2) disassembly, (3) inspection after disassembly, (4) cleaning, (5) repair, and (6) reassembly.
2. Oiling is done during reassembly.
3. The probable cause when the stem pulls out of the case is a loose detent screw.
4. If a watch cannot be fully wound, the trouble is probably caused either

by a broken mainspring, or by the barrel cover becoming disengaged from the barrel.

5. When the hands are loose they should be tightened and positioned so that when the watch is set for 12 o'clock both hour and minute hands are pointed at the figure 12 on the dial.
6. The probable causes of trouble when a watch runs too slow are: a gummy hairspring, balance rim that strikes another part of the watch, regulator pins which are spread too far apart, a bent balance staff, or a broken balance jewel.
7. The best method for removing the hands of a watch is to use a plunger-type hand remover to lift them off vertically.
8. The mainspring should be inserted into a watch barrel by using a mainspring winder. The winder is inserted into the barrel, one end of the mainspring is hooked to the inside of the barrel, and the entire mainspring then pressed into it.
9. Additional tools needed in Navy clock repair are a 6-inch screw driver, a pair of large tweezers and a special mainspring key.

# CHAPTER 6

## MAKING AND FITTING WATCH PARTS

1. Draw filing is the process of filing the edge of a piece of metal, and is done by moving the file lengthwise over the edge, usually while the piece is held in the horizontal position.
2. A newly-fabricated steel spring is hardened by first heating it to a cherry red color, then plunging it into cold water. It is tempered by heating again to a light yellow straw color, and quenching it in oil.
3. To remove a broken balance staff, the balance assembly is taken out of the movement, the roller table is driven off the staff with a roller remover and staking tool, and then the hub of the staff is turned off with a graver. (This is the accepted procedure for removing a standard rivet-type balance staff.)
4. To tighten a loose cannon pinion, seat it on a tapered round broach and move it slightly forward; then, using a small pair of cutting pliers whose edges have been rounded off, tighten the cannon pinion at its slot.
5. In replacing a watch stem, a new stem is inserted into the watch movement, with the crown loosely screwed on it, and the threaded end of the new stem is shortened by small amounts (using cutting pliers and file), its length being frequently checked by placing the stem in the movement; the crown is then tightened and the finished stem placed in the movement.
6. In 1704, jewels were first used as watch bearings by Nicholas Facio, Italian scientist and mathematician.
7. The jewel locations in a 7-jewel watch are: Two balance hole jewels

(one at each end of the balance staff); one roller jewel; and two pallet jewels.

8. The jewel locations in a 17-jewel watch are: The 7 jewels found in 7-jewel watches; plus a hole jewel at each end of the escape wheel; plus a hole jewel at each end of the pallet arbor; plus a hole jewel at each end of the fourth wheel staff; plus a hole jewel at each end of the third wheel staff; plus a hole jewel at each end of the center-wheel staff.
9. Friction jewels are jewels that have straight edges and are designed to fit tightly, by friction, into the mounting.
10. The customary clearance between a hole jewel and an end stone jewel is 0.02 mm.
11. A watch mainspring of correct length has 11 to 13 turns.
12. When a mainspring that is too long is installed in a watch, the spring will not have enough space in the barrel to unwind fully, so the watch will not run its full time.
13. The main or time train changes the slow motion of the mainspring barrel into a fast motion, causing the wheel carrying the minute hand to make one turn in the same time (one hour) that the escapement makes the required number of beats (usually 18,000 in pocket watches).
14. The dial train changes a fast motion into a slow one, and governs the distance that the hour hand travels to one turn of the minute hand.
15. The power of a mainspring decreases irregularly during the course of of the day. A considerable amount of power has been lost after 3½ hours, and after 24 hours the power has been reduced to about one-half its initial value.
16. The number of turns of a pinion geared to a wheel may be determined by dividing the number of teeth in the wheel by the number of leaves in the pinion.
17. The third wheel in this train has 75 teeth. Note: — This answer is obtained by using the formula for the number of beats per hour, $\frac{C \times T \times F \times 2 \times E}{t \times f \times e}$, and substituting the given values for the existing wheel teeth and pinions: $\frac{80 \times T \times 80 \times 2 \times 15}{10 \times 10 \times 8} = 18{,}000.$

$$T = \frac{18000 \times 800}{80 \times 80 \times 30} = 75 \text{ (number of teeth in third wheel)}$$

18. Magnetism, if present, can be detected by placing a small compass on the top of the balance cock; if the watch is magnetized, the compass needle will vibrate back and forth, sometimes making a complete revolution.
19. A watch may be demagnetized by inserting it for 3 or 4 seconds into the coil of a demagnetizing machine.

# CHAPTER 7

## ADJUSTING THE ESCAPEMENT

1. The escapement allows the power of the mainspring to be transmitted intermittently from the train to the balance, where the energy is used up at a uniform rate.
2. Banking to the drop means positioning the banking pin to a point where the escape wheel teeth will just clear or *let off* the pallet.
3. When we refer to *lock* we mean the amount of overlap between the pallet stone and the escape wheel tooth.
4. When we refer to *drop* we mean the distance that a tooth of the escape wheel travels, or drops, when it passes from the let-off corner of a pallet stone to the locking face of an intercepting pallet stone.
5. When we refer to *jewel pin shake*, we mean the clearance between the jewel pin and the horns of the fork when the pin is passing out of the fork slot at the time of the drop.
6. When we refer to *slide*, we mean the distance that the pallet stone slides on the escape wheel after the balance is moved from the position in which the jewel pin shake is tried.
7. *Strong lock* is the condition in the escapement adjustment which results when both pallet stones are moved OUT an equal distance.
8. *Strong lock* increases the jewel pin shake and the guard pin shake, and makes the drops unequal.
9. *Light lock* is the condition in the escapement adjustment which results when both pallet stones are moved IN an equal distance.
10. *Light lock* decreases the jewel pin shake and the guard pin shake.
11. A pallet warmer, an alcohol lamp, tweezers and some shreds of shellac are needed when moving pallet stones.
12. The jewel pin should always be rigidly fixed in the perpendicular position.
13. *Close outside* is a condition of the escapement adjustment caused by moving the *R* stone out and the *L* stone in.
14. To correct *close outside* and obtain a perfect lock, the *L* stone must be moved out and the *R* stone moved in.
15. *Close inside* is a condition of the escapement adjustment caused by moving the *L* stone out and the *R* stone in.
16. To correct *close inside* and obtain a *perfect lock*, the *R* stone must be moved out and the *L* stone moved in.
17. Moving the *R* stone in and the *L* stone out decreases the draw on both stones.
18. Moving the *R* stone out and the *L* stone in increases the draw on both stones.
19. The three final escapement tests that should be made after the escapement has been matched are: (1) slide, (2) safety action and (3) jewel pin freedom (shake).

20. After the escapement has been matched, the slide adjustment is made by turning each banking pin slightly away from the line of centers. It is done to ensure enough freedom for the pallet stones to slide on the escape wheel teeth.
21. After the escapement has been matched, the safety action is checked by moving the balance slowly so that the jewel pin passes in and out of the fork slot. The train is then reversed to make sure that the jewel pin will readily re-enter the fork slot from both sides.
22. After the escapement has been matched, the jewel pin freedom is checked by moving the balance wheel until the jewel pin engages the fork slot, then reducing the lock by moving the jewel pin towards the line of centers until impulse begins, and noting whether or not the jewel pin freedom is excessive.
23. To obtain adjustment of a watch in two horizontal positions, the correct weight of the balance wheel in the dial up and dial down positions is established by determining the watch's timing through the use of the timing machine, and if necessary manipulating the mean-time screws on the balance wheel until a correct rate (neither gaining nor losing) is shown in these positions.

    To obtain adjustment of a watch in three vertical positions, the balance wheel is poised by adding timing washers or moving the mean-time screws. The watch's rate is then tested on the timing machine for pendant up, pendant right, and pendant left positions. If a gaining or losing rate is still shown in one or more of these positions, the poising is repeated until a correct rate is shown in all of these positions.
24. If a timing machine chart record slopes downward and drops six divisions on a 30-second test, the watch is losing 30 seconds per day.

# CHAPTER 8

# TYPEWRITER REPAIR TOOLS

1. The nineprong pliers are a special kind of pliers having three sets of forming jaws. They are used for forming the keylevers of all makes of typewriters.
2. Typewriter peening pliers are used for spreading the metal and raising or lowering the keylevers.
3. Twisters are special Underwood typewriter wrenches used mainly for key-forming.
4. Soldering is a simple process for joining metals by using alloys having a melting temperature below 700°.
5. The ABC's of soldering are: (1) the surface to be soldered must be clean of all grease, oxides, and other foreign matter, (2) the surface to be soldered must be heated to a temperature just hot enough to

melt the solder, (3) a flux must be used that will melt at temperatures below the melting point of the solder, in order that it will not form pits or cavities in the soldered joint, (4) all traces of corrosive flux must be removed after the joints have been made.

6. A flux is any chemical substance or mixture used to clean the surfaces of metals so as to promote melting.
7. When the wick of an alcohol blow torch is lighted, the flame heats the jet tube and causes the liquid alcohol in the container to vaporize and expand. This forces the alcohol vapor out of the jet opening, where it is ignited to form a hot, light blue flame.
8. The type soldering gage is a special holder or fixture which supports a typebar outside the machine while a new typehead is being soldered onto it.
9. Brazing is the method of joining metals by means of molten alloy having a melting point above 1000° F.
10. Three cleaning solutions are commonly used in Navy typewriter repair. They are, *first*, a solution for general cleaning purposes, often made up of 1 part magnosol, 3 parts of varsol and 5 parts of water; *second*, a solution which gives the cleaned machine a thin coat of oil, made up of 80 percent paint thinner and 20 percent of lubricating oil; and *third*, a solution of alcohol, used for cleaning the rubber parts of the machine.
11. Cylinder diameters of all makes of typewriters are not the same. The cylinders of the Underwood and the L. C. Smith are both 1.750 inch, but those of the Remington and the Royal are smaller, i.e. 1.594 inch and 1.486 inch, respectively.
12. To smooth down rubber that is not hard, grooved or swollen, take a a piece of emery cloth moistened with alcohol and, starting at one end of the cylinder, twist and at the same time slide the cylinder through the emery cloth until the other end is reached, being sure the cylinder is the same diameter throughout its whole length.

## CHAPTER 9

## UNDERWOOD TYPEWRITER

1. The elementary typewriter-repair procedure can be broken down into these 4 operations: inspection before disassembly, disassembly, cleaning, and reassembly and adjustments.
2. You can decrease the clearance between the fixed and loose dog by stoning the side of the loose dog which contacts the rocker.
3. The term 6-o'clock position is used to describe the position when the escapement wheel is in the rest or normal position and the face of the loose dog is flush with the face of the starwheel tooth.
4. The ring and cylinder adjustment is the positioning of typebar and cylinder so that when a typebar is in the foreward position against

the segment ring and cylinder, it will strike both segment ring and cylinder at about the same time.

5. On feet is the term used to describe the type striking and printing on the cylinder with equal pressure on the top, sides, and bottom of the type face.
6. Motion is the term used to describe the horizontal alinement of the bottoms of the capital letters with the bottoms of small letters.
7. The type alinement is the last adjustment made because all other adjustments directly or indirectly pertain to the alinement of type.
8. If type prints more than .003 inch above or below the writing line, the typehead should be resoldered to the typebar.

## CHAPTER 10

## REMINGTON TYPEWRITER

1. The purpose of the keylever upstop is to keep all keylevers level with each other.
2. The Remington connecting link has 10 different torque-forms.
3. The typebar should rise about one-half inch from the typebar cushion before the keylever picks up the ribbon universal bar.
4. The clearance between the loose dog and the fixed dog on the Remington is .043 to .045 inch.
5. The difference between the pica escapement wheel and the elite escapement wheel is that the pica has 15 teeth and the elite has 18 teeth.
6. The space key should have $\frac{1}{16}$-inch additional movement before it contacts the space key downstops.
7. The carriage should travel five or six spaces before it contacts the space key downstops.
8. The six steps followed in adjusting on feet and motion on the Remington are (1) the rear shift toggle lever stop screw (2) the lever shift toggle lever eccentric, (3) the rear segment shift stop screw, (4) the front shift toggle lever stop screw, (5) the upper shift toggle lever eccentric, and (6) the front segments shift stop screw.

## CHAPTER 11

## ROYAL TYPEWRITER

1. The two special segment assembly screws on the Royal are used to hold the segment rails intact when the segment is removed from the machine.
2. There should be $\frac{1}{64}$-inch clearance between the escapement roll and the loose dog.
3. When the carriage is at the extreme right or left position, the ball and pinion should be three teeth away from the end of the bottom rail.

4. The ring and cylinder adjustment is made by first loosening the bottom rail binding screws, and adjusting with the ring and cylinder adjusting screws.
5. The upper case letters are used to get on feet adjustment.
6. The distance between the vertical line of one *i* and the vertical line of the other *i* should be $\frac{1}{10}$ inch.
7. The top of the spacebar should set one-fourth inch below the lower bank of the keytops.

## CHAPTER 12

## L. C. SMITH TYPEWRITER

1. The standard typewriter adjustment not made on the L. C. Smith machine is the ring and cylinder adjustment.
2. The loose and rigid dogs are taken from the rocker before cleaning so the felt pads may be removed.
3. The five sizes of the variable rollers are: .091 inch, .094 inch, .096 inch, .099 inch and .102 inch.
4. With the starwheel in rest position, three-fourths of the star wheel tooth should be engaged by the loose dog.
5. The on feet adjustment is made with the on feet adjusting screw.
6. With a machine in correct adjustment, when the typebars are 1⅝ inch to 1⅞ inch from the cylinder the typebar should pick up the universal bar.
7. The raising or lowering of a typebar is accomplished by means of its binding screw.
8. The period and comma characteristics may be prevented from making holes in the paper, by adjusting their stops on the keylever comb.

## CHAPTER 13

## PRESSURE AND VACUUM GAGES

1. The 4½-, 6-, 8½-, and 12-inch (dial size) pressure and vacuum gages are those most commonly used on naval vessels.
2. The bent Bourdon tube straightens out under pressure, and as it straightens it moves a pointer around a calibrated dial.
3. Bourdon gages are used for measuring pressures of 15 p.s.i. and up.
4. The red extra hand in Navy dial gages indicates the normal working pressure.
5. The atmosphere exerts a pressure of approximately 30 inches of mercury or 14.7 p.s.i. absolute pressure.
6. Most gages are calibrated to read zero for atmospheric pressure.
7. Pressure is force per unit of area.
8. To change a gage reading of atmospheric pressure to absolute pressure, add 14.7, or roughly 15, to the gage reading.

9. A compound Bourdon gage employs a single Bourdon tube of such great elasticity that its movement allows measurements of vacuum to the left, and of pressure to the right, of a zero point.
10. The hydraulic Bourdon gage is the type gage used to indicate the heavy pressures on hydraulic rams; the connecting links on these gages are slotted so as to prevent the pointer from slamming back to zero when the ram is suddenly released.
11. A duplex Bourdon gage is one in which two separate Bourdon-tube mechanisms are installed with two pointers swinging across the same scale, each pointer acting independently and indicating a separate pressure.
12. A differential pressure gage is equipped with two Bourdon-type tubes so connected as to measure the *difference in pressures* between two pressure lines on a dial, with the zero at the top center and the dial reading both clockwise and counterclockwise.
13. The four conditions most often requiring adjustment in Bourdon gages are: pointer calibration, sticky or sluggish action, incorrect rate of motion, and angle of pull.
14. To remedy a sluggish pointer action the bearings and gear teeth should be cleaned, and the hairspring adjusted so that all backlash is eliminated.
15. The motion of a Bourdon gage can be adjusted by moving its slotted adjustment slide either out or in to compensate for such a condition. The slide is pushed OUT when the pointer moves *too fast*, and IN if the pointer moves *too slowly*.
16. The 6-inch metal case gage that was used near corrosive fumes should be replaced with a new 4½-inch gage in a phenol plastic case.
17. The operating mechanism of a diaphragm gage consists of a slack leather diaphragm and a phosphor bronze spring attached to a pointer mounted on a pivot bearing. The diaphragm transmits the force of the air pressure to the counterweighted pointer, and produces on the scale a reading in direct proportion to that force.
18. The diaphragm gage offers a sensitive and reliable means of indicating small pressure differences without the use of liquid, which is sometimes difficult to read accurately when the ship rolls.
19. Manometers are used to measure low pressures and small pressure differences, or *drafts*.
20. Pressures up to 15 p.s.i. above and below atmosphere can be measured with manometers.
21. Pressure gage movements, or linkages, should never be oiled, because oil attracts dirt and becomes gummy. This makes the gage action sluggish and results in inaccurate readings.
22. Pressure gages should be tested at least every 6 months, or whenever they are suspected of being inaccurate, (except high-pressure gages, which should be tested once a year.)

23. The pneumatic gage comparator is a portable gage tester, and is especially valuable for in-place testing of gages that may have been damaged by excessive pressure, extreme vibration or shock.
24. (Make a schematic drawing of the pneumatic gage comparator and label its principal parts.)
25. A hydraulic deadweight gage tester operates on the principle of hydrostatic pressure created by placing weights on a piston of known area. The weighted piston applies pressure to a fluid (oil) in the cylinder, and thence to the gage through a system of piping.

# CHAPTER 14

## THERMOMETERS, PYROMETERS, AND COMBUSTION CONTROL INSTRUMENTS

1. The chief advantages of mercury from the standpoint of temperature measurement are its high boiling point, its low freezing point, its almost total lack of evaporation at the temperatures for which it is used, and its nonadherence (when chemically pure) to the inside walls of the stem.
2. The three main elements of distant-reading indicating-dial thermometers of the Bourdon-type are: a bulb for immersion at the point where the temperature is to be read, a capillary tube suitably armored, and a Bourdon-tube pressure gage.
3. If the mercury in a thermometer becomes separated, hold the thermometer by the upper end and make several full-arm swings to correct the trouble. If this does not suffice, heat the bulb carefully until the rising temperature brings the two parts of the mercury together.
4. A pyrometer is an instrument for measuring temperatures, particularly those beyond the range of industrial thermometers, by means of electric resistance or the production of a thermoelectric circuit.
5. Since the pyrometer excels the simple mercurial thermometer in range, sensitivity and adaptability, it can be used in many places where the ordinary thermometer is impractical.
6. The indicating resistance thermometer works on the same principle as the pyrometer, being calibrated to measure temperature through the increase in the electrical resistance of certain metals with temperature.
7. The superheater temperature alarm has a Bourdon tube in the shape of a helix attached to a cantilever arm. When the temperature reaches the upper safe operating limits of the superheater (say 800° F.), the cantilever arm closes the switch and thus causes a warning horn or howler to sound.
8. A smoke indicator is an illuminated lens and mirror periscope-type instrument so installed in the uptake of a boiler that by looking

through an eye-piece, the operator can tell from the amount and color of the smoke whether furnace combustion conditions are normal.

9. The chemical $CO_2$ indicator and recorder is used for determining and recording the carbon dioxide gas in the stack gases.
10. The flue gas analyzer gives more accurate results than the $CO_2$ recorder and the smoke indicator. It is used to supplement the information obtained from those two other sources.
11. The portable vapor indicator is used to detect all kinds of flammable or explosive gases and vapors, such as in tanks, voids, coffer dams, and similar locations.

# CHAPTER 15

# PNEUMERCATORS, FLUID METERS, AND SPEED INDICATORS

1. The hydrostatic principle is the most accurate known for measuring pressures.
2. The hydrostatic-type tank level indicator operates on the principle of balancing a head of liquid in a tank against a column of mercury or other indicating medium enclosed in a gage.
3. A meniscus is the curved upper surface of a liquid column.
4. The three principal parts of the Pneumercator gage are: an indicating gage (usually a column of mercury) of a size suitable for the tank; a balance chamber at the bottom of the tank, and metallic tubing, enclosed in conduits, connecting the gage to the balance chamber.
5. With the Pneumercator gage the liquid in the tank traps air in the balance chamber and tube line and compresses it against the indicating column, causing it to rise in the glass tube of the gage in proportion to the depth of liquid in the tank.
6. The Levelometer gage differs from the Pneumercator gage in that it employs a flexible bellows dial-type indicator instead of a liquid-in-tube indicator.
7. The Liquidometer is a mechanical-type tank level indicator which operates on the balanced hydraulic system, with the operative power derived from a mechanical float and arm movement.
8. The disk-type commercial fluid meter operates by displacement of the liquid being measured; a pin extending from a moving bearing rotates a gear counter drum above the liquid chamber and indicates the quantity of liquid being passed.
9. If a disk-type fluid meter has stopped registering, it should be inspected first to make sure that liquid was actually flowing in the line, then checked to see whether the trouble is in the register, in the submerged works, or inside the meter body.
10. If a disk-type fluid meter over-registers erratically, the indication is

that air, steam, or other gases are being passed through the meter along with the liquid.

11. Tachometers are used to measure shaft speeds in revolutions per minute.
12. The centrifugal-type tachometer depends for its action upon the centrifugal force of three revolving weights in a mechanism commonly known as a governor, each weight being connected with a fixed spider on the governor shaft by a hinged pin that allows it to swing outward as the speed is increased.
13. The vibrating-reed resonance tachometer operates simply by contact with the machine under test, the speed being indicated by the visible vibration of accurately tuned steel reeds, each tuned to a different frequency and mounted with their free ends visible.
14. The particular advantage of the vibrating-reed resonance tachometer is that it can be used to measure the speeds of shafts which are not readily available, as, for example, with steam turbines.
15. Revolution counters are maintained in good operating condition by (1) keeping them covered to prevent dust or dirt from settling in the mechanism, (2) keeping the revolution counter gears well lubricated with a low-viscosity lubricant, (3) frequently oiling all rotating parts with a clean, clear oil, and (4) keeping their external parts coated with an approved rust-preventing compound.

# CHAPTER 16

## ELECTRICAL MEASURING INSTRUMENTS

1. When an electrical meter is received for mechanical repairs, it should first be checked for the following minor faults: (1) Case or glass broken, (2) pointer bent, (3) missing nuts or screws, and (4) loose terminals.
2. Broadly speaking, electrical meter troubles consist of first, failure of the meter to indicate, and second, failure to indicate properly.
3. Six common mechanical faults in an electrical meter which would make it fail to indicate are: (1) a sticking pointer, (2) element jarred out of its jewel bearings, (3) pivots mounted too tightly in the jewel bearings, (4) a sticking damping vane, (5) the damping disk touching the magnet, and (6) broken pivots.
4. Six common mechanical faults in an electrical meter which would make it give an incorrect reading are: (1) static or rolling friction of the moving element, (2) pointer stalling in up-scale position, (3) movement out of balance (4) control spring coils touching, (5) loose or bent pointer, and (6) a shifting of the zero reading.
5. The condition of the jewel bearings and the pivots in portable electrical meters can easily be checked by rotating the meter about the

axis of rotation of its moving element; if the jewels and pivots are intact, the pointer will be momentarily deflected.

6. In repairing the control springs of electrical meters it is important that: (1) the radius of each bend should be kept as large as possible, (2) the coils of the spring should be made as evenly as possible so they will not touch each other or adjacent parts when the spring is compressed, and (3) the soldering iron should not be held on the spring too long so as to anneal it at the point of contact, and thus cause uneven elasticity.

# APPENDIX II

## SELECTED READING LIST

(*Watch and clock repair*)


1. *Practical Benchwork for Horologists*, by Louis and Samuel Levin; Levin & Son, Los Angeles, California. 1946
2. *Modern Watch Repairing and Adjusting*, by John J. Bowman and E. Borer; Henry Paulson & Co., Chicago, Ill. 1941
3. *Modern Methods in Horology*, by Grant Hood; Bradley Polytechnic Institute, Peoria, Ill.
4. *Practical Watch Repairing*, by Donald DeCarle; I. Pittman & Sons, London, England. 1946
5. *With the Watchmaker at the Bench*, by Donald DeCarle; I. Pittman & Sons, London, England. 1933
6. *The Junior Watchmaker*, by A. G. Thisell; A. G. Thisell, Elgin, Illinois. 1925
7. *Science of Watch Repairing Simplified*, by A. G. Thisell; Henry Paulson & Co., Chicago, Illinois. 1943
8. *A Practical Course in Horology*, by H. C. Kelly; American Horologist, Denver, Colorado.
9. *Circular Pallet Detached Lever Escapement*, by H. L. Beehler; Horological Institute of America, Washington, D. C. 1942
10. *Manipulation of Watch Hairsprings*, by H. L. Beehler, Horological Institute of America, Washington, D. C. 1942
11. *Time and Timepieces*, by Willis I. Milham; MacMillan & Co., New York, N. Y. 1945
12. *It's About Time*, by P. M. Chamberlain and Mrs. P. M. Chamberlain, Keene, N. Y. 1941


NOTE. — Membership in the Horological Institute of America, National Bureau of Standards, Washington 25, D. C,, at $5.00 a year, includes receipt of the Bulova School of Watchmaking Training Course, also the monthly issues of the H. I. A. Journal, their official publication. Membership in this society is recommended for all who really want to learn watch and clock repairing.

# APPENDIX III

# QUALIFICATIONS FOR ADVANCEMENT IN RATING

## INSTRUMENTMEN (IM)

Rating Code No. 190

GENERAL SERVICE RATING

Instrumentmen install test, calibrate, overhaul, and repair mechanical instruments, such as meters, gages, office machines, watches, and clocks. (This does not include chronometers, electronic devices, interior communications equipment, or aircraft and optical instruments.) Work from blueprints and schematic drawings; recondition instruments, and select and set jewels in instruments, watches, and clocks. Keep records of work done in repair shop; prepare requisitions for spare parts and supplies. Repair mechanical parts of electrical instruments.

EMERGENCY SERVICE RATINGS

| Title | Abbr. | *Rating Code No.* | Definition |
|---|---|---|---|
| Instrumentmen W | IMW | 191 | Repair, clean, and adjust watches and clocks (except chronometers) used in the Navy. Are assigned to repair ships and shore stations. |
| Instrumentmen O | IMO | 192 | Maintain and repair typewriters and other office equipment at large shore installations or aboard tenders. |
| Instrumentmen I | IMI | 193 | Install, test, calibrate, overhaul, and repair mechanical instruments, such as meters, gages, and hairspring instruments. Repair mechanical parts of electrical instruments. Are assigned to repair ships and shore stations. |

| Group Code Numbers | Group Titles | General Service | Emergency Service | | |
|---|---|---|---|---|---|
| | | IM | IMW | IMO | IMI |
| 37200 — 37299 | Instrument repairmen | X | | | X |
| 37300 — 37399 | Watch and clock repairmen | X | X | | |
| 37600 — 37699 | Office machine repairmen | X | | X | |
| 38300 — 38399 | Electricians, power and lighting | X | | X | |

| QUALIFICATIONS FOR ADVANCEMENT IN RATING | Applicable Rates IM | IMW | IMO | IMI |
|---|---|---|---|---|
| .100 PRACTICAL FACTORS | 190 | 191 | 192 | 193 |
| .101 TOOLS | | | | |
| Use and care for hand tools commonly employed in: | | | | |
| Watch repair. | 3,2,1,C | 3,2,1,C | | |
| Office machine repair. | 3,2,1,C | | 3,2,1,C | |
| Instrument repair. | 3,2,1,C | | | 3,2,1,C |
| Use and care for common power-driven tools, such as jeweler's lathe and drills employed in instrument repair. | 2,1,C | 2,1,C | 2,1,C | 2,1,C |
| .102 MEASURING INSTRUMENTS | | | | |
| Use and care for measuring devices commonly employed in: | | | | |
| Watch repair. | 3,2,1,C | 3,2,1,C | | |
| Office machine repair. | 3,2,1,C | | 3,2,1,C | |
| Instrument repair. | 3,2,1,C | | | 3,2,1,C |
| .103 BLUEPRINTS | | | | |
| Read and work from blueprints and schematic drawings supplied by instrument manufacturers. | 3,2,1,C | 3,2,1,C | 3,2,1,C | 3,2,1,C |
| .104 TEST EQUIPMENT | | | | |
| Use such test equipment as tachometer testers, dead weight gage testers, vacuum gage testers, and watch rate recording machines in the general check-up and adjustment of instruments. | 3,2,1,C | 3,2,1,C | | 3,2,1,C |
| .105 SOLDERING AND BRAZING | | | | |
| Solder and braze, using a gas torch or electrical equipment. | 3,2,1,C | 3,2,1,C | 3,2,1,C | 3,2,1,C |
| .106 MAINTENANCE AND REPAIR | | | | |
| Disassemble, clean, reassemble, and lubricate clock movements. Refinish watch parts. Adjust a watch escapement. | 3,2,1,C | 3,2,1,C | | |
| Disassemble, clean, reassemble, lubricate, and make adjustments on any standard office machine. | 3,2,1,C | | 3,2,1,C | |
| Dismantle, clean, test, adjust, and assemble instruments, such as precision gages and meters which record speed, revolutions, temperature, pressure, and vacuum. | 3,2,1,C | | | 3,2,1,C |
| Repair watches and clocks not requiring overhaul. | 2,1,C | 2,1,C | | |
| Make repairs to common mechanical instruments, such as tachometers and tank level indicators. Make minor repairs to the following types of gages: Bourdon | | | | |

| | IM | Applicable Rates IMW | IMO | IMI |
|---|---|---|---|---|
| **.106 MAINTENANCE AND REPAIR (CONT.)** | | | | |
| tube, simplex, duplex, depth, external pressure, compensated depth, hydraulic, differential pressure, and compound | 2,1,C | | | 2,1,C |
| Analyze troubles reported by office machine operators and make any necessary adjustments and repairs. | 2,1,C | | 2,1,C | |
| **.107 JEWELS** | | | | |
| Select and fit receiving and discharging pallet stones, roller jewels, and mounted or friction jewels. | 2,1,C | 2,1,C | | 2,1,C |
| **.108 MANUFACTURE** | | | | |
| Manufacture simple instrument parts from steel, brass, german silver, or copper. Make springs from flat steel stock; harden, temper, and finish the part. | 2,1,C | 2,1,C | | 2,1,C |
| **.109 WATCH ASSEMBLY** | | | | |
| Disassemble, clean, reassemble, lubricate, and regulate a watch movement to Navy specifications. Fit ready-made watch parts, such as staffs, mainsprings, stems, and crowns. | 2,1,C | 3,2,1,C | | |
| Adjust and regulate a watch to five positions. | 1,C | 2,1,C | | |
| **xxx.200 EXAMINATION SUBJECTS** | | | | |
| **.201 NOMENCLATURE** | | | | |
| Standard nomenclature used in the repair of: | | | | |
| Watches and clocks. | 3,2,1,C | 3,2,1,C | | |
| Office machines. | 3,2,1,C | | 3,2,1,C | |
| Instruments. | 3,2,1,C | | | 3,2,1,C |
| **.202 THEORY** | | | | |
| Fundamentals of hydraulics, mechanics, and electricity applicable to instruments. | 3,2,1,C | | | 3,2,1,C |
| Fundamentals of mechanics, and electricity applicable to clock and office machine repair. | 3,2,1,C | 3,2,1,C | 3,2,1,C | |
| **.203 INSTRUMENTS** | | | | |
| Construction and principles of operation of common mecnanical instruments. | 3,2,1,C | | | 3,2,1,C |
| **.204 LUBRICANTS AND SOLVENTS** | | | | |
| Lubricants, corrosion preventives, cleaning solutions, and solvents used in: | | | | |
| Watch and clock repair. | 3,2,1,C | 3,2,1,C | | |
| Office machine repair. | 3,2,1,C | | 3,2,1,C | |
| Instrument repair. | 3,2,1,C | | | 3,2,1,C |
| **.205 TESTING PROCEDURES** | | | | |
| Test procedures for testing: | | | | |
| Watches and clocks. | 1,C | 2,1,C | | |
| Office machines. | 1,C | | 2,1,C | |
| Instruments. | 1,C | | | 2,1,C |
| **.206 MAGNETISM** | | | | |
| Effect of magnetism on a clock and means of removing it. | 3,2,1,C | 3,2,1,C | | |
| **.207 CHEMICALS AND COMPOUNDS** | | | | |
| Use of cyanide, ammonia, alcohol, shellac, wax, and other chemicals and compounds used in watch and clock repair. | 3,2,1,C | 3,2,1,C | | |

| | IM | IMW | IMO | IMI |
|---|---|---|---|---|
| | | Applicable Rates | | |
| .208 MAINTENANCE AND REPAIR<br>Outline the following processes with reference to a standard Navy clock: disassembly, cleaning, replacement of balancing staff, reassembly, lubrication, and regulation on watch recording machine. | 3,2,1,C | 3,2,1,C | | |
| .209 MAINSPRINGS<br>Construction and function of mainsprings. | 2,1,C | 3,2,1,C | | |
| .210 WATCH MOVEMENT TRAIN<br>Trace the power from the mainspring through the entire train of watch movement. | 2,1,C | 3,2,1,C | | |
| .211 GEAR TRAIN<br>Compute a gear train and ascertain the size and number of teeth in a missing wheel or pinion. | 2,1,C | 2,1,C | 2,1,C | 2,1,C |
| .212 TYPEWRITER CHECKING<br>Outline the procedure for check of the following: alinement of type, backspacer, tabulator, and ribbon guide. | 2,1,C | | 3,2,1,C | |
| .213 OPERATING PRINCIPLES<br>Principles of operation of standard office machines. | 2,1,C | | 3,2,1,C | |
| .216 SAFETY PRECAUTIONS<br>Safety precautions to be observed in using hand tools and in operating common power-driven tools. | 3,2,1,C | 3,2,1,C | 3,2,1,C | 3,2,1,C |
| .218 ORGANIZATION<br>Organization of repair facilities at own activity. | 3,2,1,C | 3,2,1,C | 3,2,1,C | 3,2,1,C |

.300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Instrumentmen advance to Warrant MACHINIST (7442) (*Instrument Technician*), broadening their training and work experience to include the functions of optical repairmen. Machinists (7442) are assigned to repair ships (tenders) and repair facilities ashore.

# APPENDIX IV

# GLOSSARY OF TERMS

## WATCHES AND CLOCKS

ADJUSTMENT OF BALANCE ASSEMBLY — The manipulation of the balance wheel with its spring and staff to secure the most accurate timekeeping possible. Three adjustments are usually made: for isochronism, temperature, and position. Much of the difference in cost and value of watches depends on this operation.

ADJUSTMENT FOR ISOCHRONISM — Manipulating the balance and balance spring so that the watch does not change its rate when the balance swings through a long arc or a short one.

ADJUSTMENT FOR POSITION — Manipulating the balance and balance spring so that the rate does not change when the watch is in different positions.

ADJUSTMENT FOR TEMPERATURE — Arranging the screws on the compensation balance so that the time of swing will be as nearly as possible the same for a considerable range of temperature. (Seldom necessary today.)

ALLOY — A mixture of two or more metals.

ARBOR — The axle on which a wheel turns.

ARKANSAS OILSTONE — A smooth oilstone (hard or soft) used for sharpening gravers, screw drivers, and tools of all kinds to a final finish.

BACKLASH (WATCH) — A small reverse movement of the wheels at the end of unwinding.

BALANCE ARC — In detached lever escapements, that part of the vibration of the balance in which it is connected with the train.

BALANCE ARM — The flat piece of metal across the center of the balance wheel which supports the balance wheel on the balance staff.

BALANCE ASSEMBLY — The balance wheel and its arbor, complete with hairspring and roller assembly.

BALANCE COCK — The projecting bar which holds one end of the balance arbor.

BALANCE SPRING — (Also called hairspring.) A fine, coiled wire, one end of which is attached to a collet fitted friction-tight on the balance staff and the other end to a stud on some stationary part of the watch, (as on balance cock or watch plate.) This spring governs the time of vibration of the balance.

BALANCE STAFF — The axis or arbor which carries the balance wheel.

BALANCE TRUING — Bending balance wheel rims back into shape to obtain perfect balance.

BALANCE WHEEL — The oscillating wheel of a watch, which, along with the balance spring, regulates the motion of the train, thus controlling the movement of the hands.

BANKING — the striking of the outside of the lever by the impulse pin due to excessive vibration of the balance.

BANKING PINS — Pins (two in number) which arrest or limit the angular motion of the lever in the lever escapement of a watch.

BANKING TO THE DROP — Positioning the banking pin to a point where the escape wheel teeth will just clear or *let off* the pallet.

BARREL — The circular metal box which contains the mainspring.

BARREL, GOING — The type of mainspring barrel having teeth cut around the outside; these teeth are in mesh with the center wheel pinion. This driving action furnishes the motive power for the watch.

BARREL HOOK — A bent pin in the barrel to which the mainspring is attached.

BARREL RATCHET — A wheel on the barrel arbor which is prevented by a dog from turning backward while the mainspring is being wound and which becomes the base against whose resistance the train is driven.

BEARING, JEWELED — A metal support inlaid with specially formed small ruby, sapphire, or diamond to minimize the friction of a pivot or pin.

BEAT — One vibration of the balance and balance spring resulting from an impulse received by means of an escapement. (See *In beat.*)

BEZEL — The grooved metal ring which holds in place the crystal or glass of a watch or clock.

BRIDGE — One of the upper plates used for the support of the wheels; the central part is cut away to provide space for one or more pivot bearings.

BURNISHED PIVOT — Highly polished end of a rotating arbor.

BURR — A small piece of metal projecting from a part, such as that left on a new wheel by a gear cutter or caused by wear between gear teeth.

CANNON PINION — The pinion with a long pipe to which the minute hand is fixed.

CAPPED JEWEL — A jewel having a protective endstone.

CENTER STAFF — The arbor attached to the center wheel which carries the minute hand.

CENTER WHEEL — The wheel in ordinary clocks and watches placed in the center of the frame on whose arbor the minute hand is carried. It is intermediate between the barrel and the third wheel.

CHRONOMETER — Any very accurate timekeeper. Usually understood to mean a timekeeper fitted with a spring detent escapement, also with a fusé (stepped barrel) and a cylindrical balance spring.

CHUCK — A device inserted in the headstock of a lathe to hold the part in position for machining or other lathe operation.

CIRCULAR ESCAPEMENT — An escapement so constructed that the central

portion of each pallet stone's impulse face stands at an equal distance from the pallet center.

CLEARANCE — The small space or distance between adjacent parts of a machine by which one part clears another. In the watch trade this space is called ENDSHAKE.

CLICK — A pawl or dog which fits into the teeth of the ratchet wheel and prevents it from turning backwards.

CLUTCH — A device in a stem-wind watch to shift the power from the stem to either the winding or the setting gearing.

CLUTCH LEVER — The lever which operates in a recess of the clutch and moves it into setting or winding position.

CLUTCH PINION — The pinion surrounding the square portion of the stem. Serves alternatively to wind and to set the watch.

CLUTCH WHEEL — The wheel which engages the setting mechanism or the winding mechanism.

COCK — A piece which serves the purpose of a bridge, but rests on one end and is held by one screw, as the balance cock of all watches.

COLLET — The collar installed on the balance staff of a watch to which one end of the balance spring is attached.

COMPENSATING BALANCE — A balance whose rim is made of brass and steel to correct for errors caused by temperature variation. The diameter increases or decreases in different temperatures so as to compensate to quicken or slow down the vibration for changes in temperature.

COUNTERSHAFT — An intermediate shaft which receives motion from a main shaft and transmits it to a working part. Used by watchmakers to reduce cutting speed.

CRESCENT — A circular notch in the edge of the roller table for the reception of the guard pin or horn.

CROWN — A grooved circular piece fastened to the stem used for winding the watch.

DEMAGNETIZING — The operation of removing magnetic properties from a piece of iron or other magnetized object.

DETENT — The device which halts and releases, at the proper instant, the escapement of a clock or watch.

DIAL — The graduated face of a timepiece.

DIAL FOOT — One of the small metal pillars attached to the back of the dial for the purpose of holding the dial in place.

DIAL TRAIN — A train of two wheels and two pinions that control the progress of the minute hand and the hour hand.

DIAL WHEELS — The wheels constituting the motion work of a watch.

DIAMANTINE — A fine white powder mixed with oil to a stiff paste; used for polishing watch parts.

DISCHARGING PALLET — That pallet over which a tooth of the escape wheel slides in order to leave from between the pallets.

DOUBLE ROLLER — A roller unit consisting of two metal disks; the upper and larger disk supports the roller jewel and is called the impulse roller;

the lower and smaller disk with the crescent notch serves as the safety roller.

DRAW — A force exerted by an escape wheel tooth upon the locking face of a pallet stone because of its slant, tending to bring the pallet lever against the banking pin and keep it there.

DROP — The distance a tooth of the escape wheel travels or DROPS when it passes from the let-off corner of a pallet stone to the locking face of an intercepting pallet stone. Drop is also defined as the space through which an escape wheel moves without doing any work.

ENDSHAKE — Clearance or spacing between adjacent parts of a watch, or freedom of pivots to move endways. Some such freedom is necessary, since there is no force to spare in a watch and too tight a fit would stop the movement.

END STONE — A small disk of jewel upon which a watch pivot rests. (Often called a cap jewel.) It is found only in the escapement.

ELINVAR — A non-rusting, non-magnetizable alloy containing iron, nickel, chromium, tungsten, silicon, and carbon. Used for balance and balance springs.

ESCAPEMENT — That part of the watch movement which controls the rate of running. It regulates the motion of the train thus distributing the power of the main-spring. It communicates the motive power to the balance.

ESCAPE COCK — The bracket which supports the upper ends of the escape wheel and pallet staff arbors.

ESCAPE PINION — The pinion on the escape wheel arbor.

ESCAPE WHEEL — The last wheel of a train; it gives impulse to the balance, indirectly. Easily identified by its teeth, which resemble those of a circular saw. The escape wheel moves forward one tooth at a time.

FORK — The part located at the end of the pallet lever, containing the slot which the roller jewel enters. The fork delivers the impulse to the roller jewel.

FORK HORN — (See GUARD PIN.)

FORK SLOT — A notch cut into the fork for the reception of the roller jewel.

FORK TOOL — A thin metal rod used to hold the balance wheel while making certain adjustments.

FRICTION JEWEL — A jewel bushing in a watch movement which has been forced into place by pressure and stays there under friction alone. (Friction jewels do not have bezels. See *jewel.*)

FOURTH WHEEL — The wheel in a watch that drives the escape pinion and to which arbor the seconds hand is attached.

GAGE — A measuring instrument or device.

GOING BARREL — (See BARREL, GOING.)

GRAVER — A specially sharpened steel tool used with a lathe for a variety of cutting operations.

GRAVITY — The pull of earthly bodies towards the center of the earth.

GUARD PIN — The small brass pin working in and out of the crescent to preserve the safety action by assuring that the pallet will be in its proper position, ready to receive the jewel pin on its return trip. (Also called fork horn.)

GIMBAL — A contrivance resembling a universal joint permitting a suspended object to tip freely in all directions. Marine chronometers are supported in their cases by gimbals.

HAIRSPRING — (Also called balance spring.) A fine coiled wire, one end of which is attached by a collet to the balance staff and the other end to a stationary part of the watch called a stud. This spring assists the balance to vibrate and governs its time of vibration.

HAIRSPRING TRUING — Revolving the balance and inspecting the hairspring and, if necessary, bending the coils back in original position.

HANDS — The revolving pointers which indicate the hours, minutes, and seconds.

HEADSTOCK — The portion of the lathe which receives the power and which holds and rotates the work.

HEAVY POINT — The point on the rim of an out-of-poise balance wheel where the force of gravity appears to be centered when the watch is operating in the vertical position.

HORNS — The circular sides of the fork that lead to the fork slot. Part of the safety action which insures the escapement continuing in action should the watch receive a shock of sufficient force to throw the lever off its banking pin during unlocking and impulse action.

IMPULSE — The push transmitted to the pallet by the escape wheel.

IMPULSE FACE — The inclined plane on end of pallet stone on which the escape wheel teeth press to produce the lift of an escapement action.

IMPULSE PIN — The jewel pin — usually a ruby — on the table roller of the lever escapement, which, playing into the fork of the lever, transmits the impulse to the balance.

IN BEAT — A watch is said to be in beat when the same amount of power is required to start the balance in one direction as in the other. That is, there is no tension exerted by the balance spring to either side when the escapement is at dead center.

INDIA STONE — An artificially produced stone used for sharpening tools. Softer than the Arkansas stone.

ISOCHRONISM — The property of a balance spring that allows it to move through long and short arcs of motion in equal time; i.e., all its vibrations, of whatever length, are made in time periods exactly equal.

JEWEL — A precious stone which is pierced to receive the pivot. Jewels are used as bushings at the ends of pivots and in other places which sustain much wear. They

1. Provide smooth bearings for the pivots.
2. Obviate corrosion.
3. Reduce the wear from abrasion.

Sapphire is the best of the jewels in use; ruby is second.

JEWEL GAGE — A needle-shaped instrument provided with a scale for measuring jewel sizes.

JEWEL PIN — (Also called roller jewel.) A long, thin jewel, usually of ruby or sapphire, suspended perpendicularly in the roller. The jewel pin is the connecting link between the pallet and the balance wheel.

JEWEL PIN SHAKE — The clearance between the jewel pin and the horns of the fork when the pin is passing out of the fork slot at the time of the "drop."

LEAVES — The teeth of pinions.

LET-OFF CORNER — The extreme tip of the pallet stone where each successive tooth of the escape wheel loses contact with the pallet stone.

LEVER — In watchmaking, a metal piece to which the pallet arms are attached, and which serves to carry the impulse to the pallet from the escape wheel.

LEVER ESCAPEMENT — A watch escapement that delivers an impulse to the balance by means of two pallet stones and a lever. The extremity of the lever has a forked slot that acts directly on a roller jewel which is attached to the balance.

LIFT — The action which takes place when the impulse face of the escape wheel tooth engages the impulse face of the pallet stone or jewel.

LOCK — The amount of overlap between the pallet stone and an escape wheel tooth.

LOCKING FACE — That side of a pallet stone which locks or overlaps the tooth of an escape wheel (upon which the teeth of the escape wheel drop).

LOUPE — Also called eye lens; a piece of glass or other transparent material whose surfaces are ground to form an image by changing the direction of light rays, resulting in magnification of an object viewed through this lens.

MAINSPRING — A long ribbon of steel that supplies the power for driving a clock or watch. It is coiled into the circular metal box of the barrel with the outer end fastened to the barrel and the inner end to the barrel arbor.

MAINSPRING ASSEMBLY — The barrel, mainspring, and arbor combination.

MAIN TRAIN — The toothed wheels that connect the barrel with the escapement, causing the minute hand wheel to make one turn while the escapement makes a required number of beats.

MEAN-TIME SCREWS — Screws used to bring a watch to time, sometimes called timing screws.

MICROMETER CALIPER — A precision measuring device for determining diameters and thicknesses. The metric-calibrated type is usually used in watch repairing.

MIDDLE-TEMPERATURE ERROR — The temperature error between the extremes of heat and cold — an error characteristic of a compensating balance and steel balance spring, because the compensation balance does not exactly meet the temperature error. The rim expands too much with

decrease of temperature and contracts too little with the increase. Hence, a timepiece can be correctly adjusted for two points only. The unavoidable error between is the middle temperature error.

MINUTE — The sixtieth part of a mean solar (sun) hour.

MINUTE HAND — Hand of a clock or watch which indicates the minutes. (First concentered with the hour hand in 1673.)

MINUTE WHEEL — The wheel which carries the minute hand and is driven by the cannon pinion.

MINUTE WHEEL PINION — The pinion on which the minute wheel is mounted and which drives the hour wheel.

MOTION — The amount of the circular movement of the balance wheel when oscillating. A motion of about $1\frac{1}{8}$ + turns is considered to be the most desirable.

MOTION WORK — The wheels in a watch which make the motion of the hour hand one-twelfth as rapid as that of the minute hand.

MOVEMENT — The watch or clock complete, without dial or case — the mechanism of the watch or clock.

NEEDLE GAGE — A measuring device consisting of a narrow scale calibrated to read the diameter of a jewel placed on its needle and pushed up into the gage.

OIL RESERVOIR — The spherical space around the pivot hole in a watch jewel where oil is stored to keep the watch lubricated.

OUT-OF-POISE — The watchmaker's term for describing a balance wheel or balance wheel assembly which is not balanced.

OVER BANKING — Pushing of the ruby pin past the lever, caused by excessive variation of the balance.

OVERCOIL — The outermost coil of a Brequet hairspring, which is carried up and over the rest of the spring.

PALLET — The metal body attached to or a part of the lever. The term includes the pallet arms and pallet stones. The pallet transmits the impulse from the escape wheel to the balance.

PALLET ARBOR — The axle on which the pallet oscillates.

PALLET ARMS — The metal body which contains the pallet stones.

PALLET STAFF — The axis of the pallet or arbor upon which it is mounted.

PALLET STONE — That part of an escapement which transmits the impulse from the escape wheel to the balance. Also defined as the jewel on the contact face of the pallet where it is struck by the teeth of the escape wheel.

PAWL — Another name for a dog, click, or ratchet.

PEGGING — The operation of using a sharpened stick of pegwood to clean or polish watch parts.

PILLAR — One of the three or four short brass posts which keep the plates at their proper distance apart.

PILLAR PLATE — The lower plate of a watch movement, nearest the dial.

PINION — The smaller of two toothed wheels which are geared into one another. The larger one is called the wheel.

PIVOT — The end of an axle or arbor which rests in a support.

PLATE — Disks of brass which form the foundation of the movement. The lower plate lies next to the dial. The upper pieces supporting one, two, or three wheels are usually referred to as bridges.

POISING — Adjusting the balance wheel so that its mass is distributed equally around the axis of rotation and the effect of the force of gravity is eliminated.

PUNCH, RIVETING — The flat-faced tool for flattening the riveting shoulder of a rivet-type staff.

PUNCH, SEATING — The tool used with the staking tool to spread the riveting shoulder when staking a balance wheel onto a rivet-type staff.

RATCHET — The pawl, or dog, which engages in the teeth of a ratchet wheel and prevents it from turning backward. It is held lightly against the periphery of the ratchet wheel by a small spring known as the ratchet spring.

RATCHET WHEEL — A wheel with triangular teeth fastened to the barrel arbor to prevent the mainspring from slipping back when it is being wound.

RATE (OF A WATCH) — The interval of time which a watch gains or loses in a given length of time, usually 24 hours.

REAMER — A small rotating finishing tool with cutting edges for enlarging or shaping a hole.

RECEIVING PALLET — That pallet stone over which a tooth of the escape wheel slides in order to enter between the pallet stones.

REGULATOR — The lever in a watch by which the pins regulating the swing of the hairspring are shifted.

REGULATOR PINS — The two small pins which embrace the hairspring and by being moved change the shape of the overcoil, and, consequently, the rate of the watch.

RIM WRENCH — A small hand tool notched at the end, used for forming balance wheel rims, etc.

ROLLER — The circular plate into which the jewel pin is set in a lever escapement.

ROLLER JEWEL — (See JEWEL PIN.)

ROLLER TABLE — A flat circular metal disk from which the roller jewel is suspended.

SECONDS HAND — The hand on the dial of a clock or watch which revolves once a minute. Sometimes small and set in a small circle of its own. Sometimes long and traversing the whole dial.

SECONDS PIVOT — The prolongation of the fourth wheel arbor to which the seconds hand of a watch is fixed.

SHAKE — The space separating the letting-off corner of the pallet from the heel of an escape wheel tooth when the opposite pallet is locked at the lowest locking corner.

SIDESHAKE — Freedom of pivots to move sideways. (See *endshake.*)

SLIDE — The distance the pallet stone slides on the escape wheel after the balance is moved from the position in which the jewel pin shake is tried.

STAKING TOOL — An anvil-type tool used with punches to fasten watch parts together, and to separate parts by exerting pressure at strategic points.

STEM — The winding arbor of a watch.

STUD — A small piece of metal pierced to receive the outer coil of the balance spring (hairspring).

STUMP — The small metal support used to hold a balance staff in position on the staking stand while the setting punch presses a balance arm down onto it.

TAILSTOCK — The portion of the lathe which was originated to support one end of the work, but now is used largely as a tool carrier (in horology).

T-REST — A support for steadying a graver while cutting on a jeweler's lathe.

THIRD WHEEL — The wheel in the train between the center wheel and the fourth wheel; it drives the fourth pinion.

TIMING SCREWS — Screws used to bring a watch to time, sometimes called mean-time screws.

TIMING WASHERS — Small washers punched out of extremely thin metal or foil, for use in poising balance wheels.

TRAIN — A series of two or more wheels and pinions, geared together and transmitting power from one part of a mechanism to another.

TRIPPING — The running past the pallet's locking face of an escape wheel tooth.

TRUING-IN-THE-FLAT — The operation of bending the rim of a balance wheel until (1) all parts of the rim lie in the same plane, and (2) the entire rim is perpendicular to the staff axis.

TRUING-IN-THE-ROUND — The operation of bending the rim of a balance wheel until it is concentric with the staff axis.

TURNING — A shaping or forming operation by use of the lathe.

UNDERCUTTING — Removing metal from the undersides of balance screws in the truing operation.

VERNIER CALIPER — A form of slide gage graduated in millimeters widely used by watch repairman. (This gage is also known as the Boley slide gage.)

WATCH ADJUSTING — The procedures employed in producing a uniform rate within well defined limits and under various conditions. Watch adjusting is divided into three branches: (1) position adjusting, (2) isochronal adjusting, and (3) temperature adjusting.

## OFFICE MACHINES

BASKET SHIFT — When the shift key is depressed and released the segment and typebars of this type of machine move up and down.

BELL CRANK — A right angle lever for communicating motion as from one bell wire to another lying at right angles to it.

CARRIAGE SHIFT — When the shift key is depressed and released, the carriage of this type of machine moves up and down.

CYLINDER — (See *platen.*)

DROP (ROYAL) — The distance the carriage travels horizontally when, after a character has been printed, the machine backspaced one space, the space bar is depressed, and the same character printed again.

ECCENTRIC — A part whose axis is not centered with that of another part.

ESCAPEMENT—The mechanism which controls the movement of the carriage

FULCRUM — The support or point of rest on which a lever turns.

KSM — Key set margin.

KST — Key set tabulator.

LOWER CASE — Print in small letters (not capitals).

MOTION — The alining on a horizontal line of the bottom of the upper case characters with the bottom of the lower case characters.

ON FEET — The adjustment made to cause the type face to print evenly with its top, bottom, and both sides.

OVERBANKING — The condition where the carriage moves one or more spaces past the position set by the margin stop.

PLATEN — The rubber covered cylinder or roller of a typewriter.

UPPER CASE — Print in capital letters.

UNDERBANKING — The condition where the carriage moves one or more spaces short of the position set by the margin stop.

## GAGES AND METERS

ABSOLUTE PRESSURE — Pressure measured above a perfect vacuum. It is the pressure indicated by an ordinary pressure gage plus the atmospheric pressure.

AMMETER — An instrument for measuring electric current (in amperes).

AMMETER, SPLIT CORE — A portable current-measuring instrument which uses the magnetic field around a current-carrying conductor to produce a deflection of an indicating pointer.

AMPERE — The unit of quantity of electric current, being that produced by one volt acting through a resistance of one ohm. (Named after A. M. Ampere, famous French physicist.)

ATMOSPHERIC PRESSURE — The pressure exerted by the atmosphere; not merely downwards, but in every direction.

BAFFLE — A plate, wall, or screen used to deflect, check, or otherwise regulate the flow of a gas, liquid, sound waves, etc.

BAROMETER — An instrument for determining atmospheric pressure and hence for judging probable changes of weather.

BATTERY (ELECTRIC) — A cell or combination of cells, which generates electrical current by chemical action.

BOURDON TUBE — A thin-walled, oval-shaped tube bent into the form of a *C*, which tends to straighten out when pressure is exerted in the tube. As the tube straightens, it is made to move a pointer around a dial.

BURETTE — A graduated glass tube, usually with a small opening and stopcock, for delivering measured quantities of liquid or for measuring the liquid or gas received or discharged.

CALIBRATION — The process of determining the capacity, or the graduations of, or to correct the readings of, as of dial instruments.

CANTILEVER ARM — A projecting beam or member supported only at one end.

CAPILLARY ATTRACTION — The action by which the surface of a liquid which is in contact with a solid is elevated or depressed.

CENTIGRADE — On the centigrade thermometer, the interval between the freezing point and the boiling point of water is divided into 100 parts or degrees, so that 0° C. corresponds to 32° F., and 100° C. to 212° F.

CENTRIFUGAL FORCE — That force which tends to drive a thing or parts of a thing, outward from a center of rotation.

$CO_2$ INDICATOR — An instrument designed to reveal the presence of carbon dioxide, a heavy colorless gas.

COMPARATOR — An instrument or machine for comparing anything to be measured with a standard instrument. Specifically, a self-contained portable pneumatic comparison-type pressure gage tester.

CONDENSATE — The product of condensation (the process of reducing from one form to another and denser form, as steam to water).

CONDUCTIVITY — The quality or power of conducting or transmitting heat, electricity, etc.

CONTROL SPRING — A small spring soldered onto the rotating mechanism of electrical meters (usually one at the top and one at the bottom of the shaft) to control and regulate the movement of the pointer.

CYCLE — When the voltage in an alternating current increases from zero to a maximum point, then decreases through zero to a maximum point in the opposite direction, then returns to zero again, a cycle is said to have been completed.

DAMPING DEVICE (ELECTRICAL) — A small metal disk mounted on the shaft of a moving element which turns between the poles of a permanent magnet. This motion sets up currents in the disk which oppose the motion of the moving magnet, resulting in a DRAG on the disk tending to stop it.

DEADWEIGHT TESTER — A hydraulic-balance type gage tester operating on the principle of subjecting the gage under test to a hydrostatic pressure created by applying weights to a piston of known area. The weighted piston applies pressure to a fluid, such as oil, in the cylinder which in turn is transmitted to the gage through a system of piping.

DIAPHRAGM POINTER GAGE — A pressure or vacuum gage containing a thin disk or membrane, whose indicating pointer moves in accord with the vibrations of the disk or membrane.

DIFFERENTIAL EXPANSION — The property of some metals or other solids to expand at different rates when heated. (See expansion coefficient.)

DIFFERENTIAL PRESSURE GAGE — A Bourdon-type gage equipped with

two Bourdon tubes so arranged as to measure the difference in pressure between two pressure lines.

ELECTRICAL RESISTANCE — The opposition offered by a substance or body to the passage through it of an electric current or magnet flux.

ELECTRODE — Either terminal of an electric source. An electrode may be a wire, a plate or other electricity-conducting object.

ELECTROMOTIVE FORCE — That which moves, or tends to move, electricity.

EXPANSION COEFFICIENT — The ratio of the increase of length, area, or volume of a body for a given rise in temperature to the original length, area, or volume. Also called coefficient of expansion.

FAHRENHEIT — On the Fahrenheit thermometer, under standard atmospheric pressure, the boiling point of water is at 212° F. and the freezing point at 32° F. above the zero of its scale.

FILAMENT — A threadlike conductor, as of carbon or metal, that is made incandescent by the passage of an electric current.

FLUE GAS (STACK GAS) — Gas taken from the flue or chimney used to convey flames, smoke, and hot gases around or through water in a boiler.

FREQUENCY — The number of cycles (as in an alternating electrical current) completed per second is called the frequency.

GALVANOMETER — An instrument for measuring a small electric current, or for detecting its presence or direction by means of the movements of a magnetic needle, or of a coil in a magnetic field.

GOVERNOR — An automatic attachment to an engine, compressor, etc., for controlling its speed.

HELIX — Anything having a spiral shape. (Mathematically, a helix is the shape of the curve formed on any cylinder by a straight line in a plane that is wrapped around the cylinder, such as an ordinary screw thread.)

HEXANE — A colorless, explosive gas of the petroleum series.

HYDRAULIC — Conveying, acting, or operating by water (or some other liquid).

HUMIDIFIER — A baffled water container having a gastight dividing wall; gas and air pass over the water surfaces and become moistened.

HYDRAULIC RAM — The plunger of a hydrostatic press.

HYDROSTATIC — The branch of physics which relates to the pressure and equilibrium of liquids.

INDUCTION (ELECTRICAL) — The process by which (1) an electrical conductor becomes electrified when near a charged body, or (2) a magnetizable body becomes magnetized when in a magnetic field, or (3) an electricity moving force is produced in a circuit by varying the magnetic field linked with the circuit.

INERT GAS — A gas which has no active chemical properties.

KEEPER — In the electrical trade, a piece of steel or soft iron used to connect the poles of a magnet to preserve the intensity of the magnetization.

KILOWATT — A unit of electrical power, equal to 1,000 watts. (A watt

is a unit of power equal to the rate of work represented by a current of one ampere under a pressure of 1 volt.)

LEVELOMETER — A gage which operates on the hydrostatic principle, employing a dial-type indicator, to measure the contents of tanks.

LIQUIDOMETER — A float-actuated, remote-reading gage operating on the balanced hydraulic principle to measure the contents of tanks.

MAGNETO — An electrical device with permanent magnets, used to generate the current for the electric ignition of internal-combustion engines, etc.

MENISCUS — The curved upper surface of a liquid column; concave when the containing walls are wetted by the liquid (as with water), and convex when not (as with mercury).

MANOMETER — A gage for measuring the pressure of gases and vapors.

OHM — The unit of electrical resistance, being the resistance of an electrical circuit in which an electrical pressure of 1 volt produces a current of 1 ampere.

PNEUMERCATOR — A hydrostatic-type tank level indicator, operating on the principle of balancing a head of liquid in a tank against a column of mercury or other indicating medium enclosed in a gage.

POLARITY (ELECTRICAL) — The particular state (positive or negative) of a body with reference to the two poles.

POWER FACTOR — The ratio of the apparent power in an electrical circuit to the true power, expressed in percent. In direct current circuits the power factor is always 1; in alternating current circuits it is usually less than 1. (For a detailed explanation of power factor, see page 219 of Electrician's Mate, *2d Class*, NavPers 10103.)

PRESSURE — Pressure is force per unit of area.

PRESSURE DIFFERENTIAL — A difference in pressure.

P.S.I. — Abbreviation for pounds per square inch.

PYROMETER — An instrument for measuring temperatures, particularly those beyond the range of mercurial thermometers, as by means of the change of electric resistance, the production of a thermoelectric current, the expansion of gases, etc.

RESISTOR — A device possessing the property of electrical resistance, used in an electric circuit for protection operation or control.

SALINITY INDICATOR — An indicating gage which measures the approximate salt content of fresh water. It operates on the principle that the electrical conductivity of water varies with its chemical impurity content.

STATIC CHARGE — A stationary charge of electricity, such as that produced by rubbing together unlike bodies, as amber and cloth, a glass rod and silk, etc.

STATIC FRICTION — The resistance to relative motion of two bodies in contact.

SUPERHEATER — A nest of tubes exposed to the flames of a furnace, through which steam from the boiler passes to be heated so that it possesses more than enough heat to maintain its existence as a dry gas.

TACHOMETER — A speed counter.

TANK LEVEL INDICATOR — A hydrostatic-type tank gage, usually operating on the principle of balancing a head of liquid in a tank against a column of mercury, or on the balanced hydraulic principle employing a float-actuated remote reading dial gage. (See Levelometer, Liquidometer, and Pneumercator.)

TEMPERATURE COMPENSATOR — A means of counteracting, or making compensation for, a variation in temperature.

TERMINAL (ELECTRICAL) — A device attached to the end of a wire or cable or apparatus for convenience in making electrical connections.

TETRABROMOTHANE — A heavy yellowish or red liquid sometimes used as a solvent.

THERMAL ALARM — A temperature alarm signal device, used on Navy vessels to give warning of excessive superheater temperatures. A light, a horn, or both types of warning may be employed.

THERMOCOUPLE PYROMETER — A temperature measuring instrument using the change of electric resistance of a conductor when heated to indicate the temperature being measured.

THERMOELECTRIC — Of or pertaining to electricity produced by the direct action of heat, as by the unequal heating of a circuit composed of two dissimilar metals.

TORQUE — That which produces or tends to produce rotation.

VACUUM — A space exhausted to a very high degree by an air pump or some other means. Vacuum (below atmospheric) pressures are usually indicated in *inches of mercury*.

VAPOR INDICATOR — An electrochemical device used to detect the presence of explosive or flammable mixtures.

VISCOSITY — The ability of a liquid to cling, or resist flowing.

VOLT — The unit of electromotive force, defined as the force which steadily applied to a circuit whose resistance is one ohm will produce a current of one ampere.

VOLTAGE — The electric potential difference, expressed in volts.

VOLTMETER — An instrument for measuring in volts the difference of potential between different points of an electrical circuit.

WATER JACKET — An outer casing holding water, through which water circulates to cool the interior, such as the enclosed space surrounding the cylinder block of an internal-combustion engine, and containing the cooling liquid.

WATT — The unit of electric power, equal to the rate of work represented by a current of one ampere under a pressure of one volt.

WATTMETER — An instrument for measuring electric power in watts.

WATT-HOUR METER — A device used to record electric energy, usually in kilowatt hours.

WHEATSTONE BRIDGE — A device for the measurement of electrical resistance, invented by Sir Charles Wheatstone, English physicist.



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